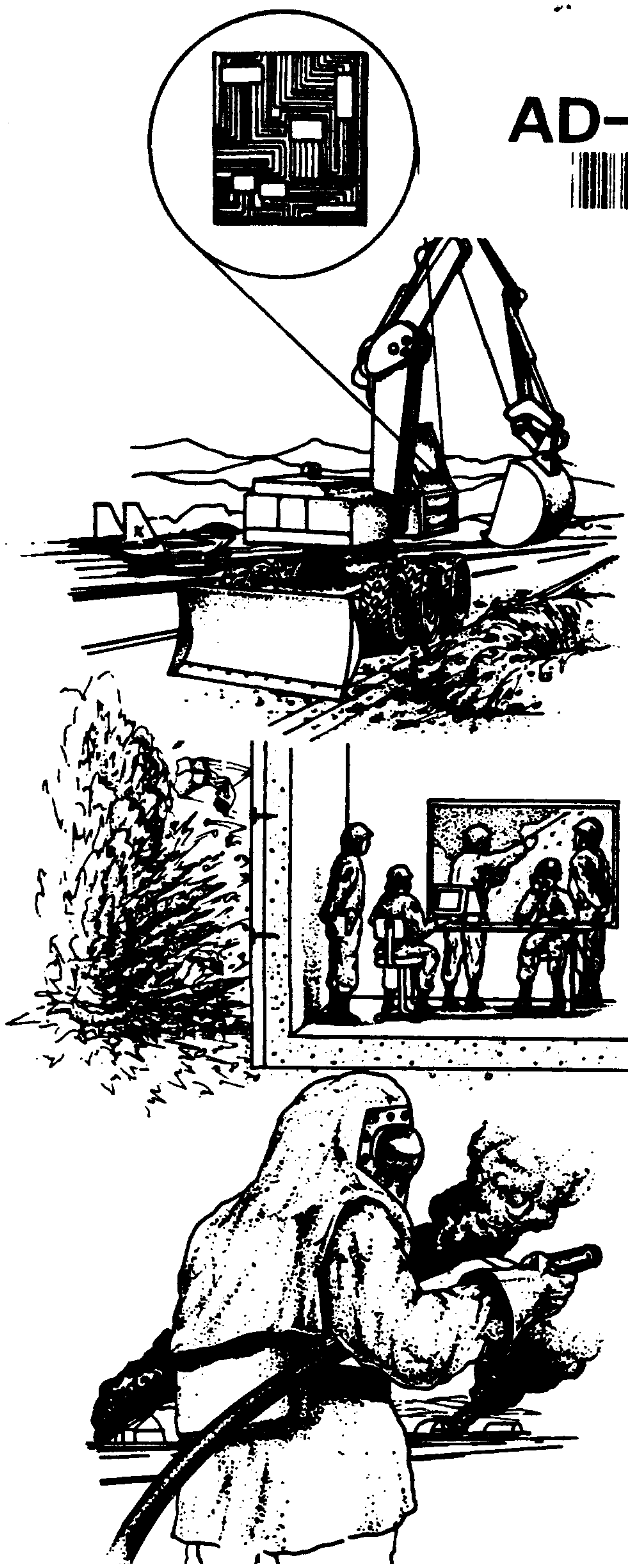
ESL-TR-92-63
Volume II

1



AIRCRAFT FIRE SENTRY
VOLUME II - APPENDICES

R.M. MUGELE
P.T. DZWILEWSKI
J.T. CILKE

APPLIED RESEARCH ASSOCIATES, INC.
7114 W. JEFFERSON AVENUE, SUITE 306
LAKEWOOD CO 80235

JANUARY 1993

FINAL REPORT

AUGUST 1990 - AUGUST 1992

APPROVED FOR PUBLIC RELEASE:
DISTRIBUTION UNLIMITED

ENGINEERING RESEARCH DIVISION
Air Force Civil Engineering Support Agency
Civil Engineering Laboratory
Tyndall Air Force Base, Florida 32403

NOTICE

PLEASE DO NOT REQUEST COPIES OF THIS REPORT FROM HQ AFCESA/RA (AIR FORCE CIVIL ENGINEERING SUPPORT AGENCY). ADDITIONAL COPIES MAY BE PURCHASED FROM:

NATIONAL TECHNICAL INFORMATION SERVICE
5285 PORT ROYAL ROAD
SPRINGFIELD, VIRGINIA 22161

FEDERAL GOVERNMENT AGENCIES AND THEIR CONTRACTORS REGISTERED WITH DEFENSE TECHNICAL INFORMATION CENTER SHOULD DIRECT REQUESTS FOR COPIES OF THIS REPORT TO:

DEFENSE TECHNICAL INFORMATION CENTER
CAMERON STATION
ALEXANDRIA, VIRGINIA 22314

REPORT DOCUMENTATION PAGE

OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 1993	FINAL 17 Aug 90 - 17 Aug 92

4. TITLE AND SUBTITLE
Aircraft Fire Sentry
Final Technical Report
Volume I - Summary; Volume II - Appendices A, B, C, and D

5. FUNDING NUMBERS
C F08635-88-C-0067
Subtask 3.14.1

6. AUTHOR(S)
R. M. Mugele, P. T. Dzwilewski, J. T. Cilke

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Applied Research Associates, Inc.
7114 W. Jefferson Ave., Suite 305
Lakewood, CO 80235

8. PERFORMING ORGANIZATION REPORT NUMBER
5636

9. SPONSORING/MONITORING AGENCY NAME(S) AND
Department of the Air Force
Air Force Development Test Center
Eglin AFB, FL 32542-5320

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
ESL-TR-92-63 vol 2

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report summarizes the development of an Aircraft Fire Sentry (AFS) system. The AFS is designed to automatically detect a fire in the cargo bay of large cargo aircraft, provide an audio and visual alarm locally, and remotely notify the nearest fire department by radio frequency link. The basic design philosophy in developing the AFS was to use commercially available fire detection hardware and radio transmitters/receivers. The finished assembly is to be lightweight and portable. The AFS is to be deployed onboard parked aircraft and left to sense fire stimulus for up to 60 continuous hours in the self-powered mode. A prototype model was designed, built, and tested for performance and reliability.

14. SUBJECT TERMS Unattended/Parked Cargo Aircraft, Aircraft Fire Detection, Fire Department Notification, Portable, Modular, Radio Frequency Operation

15. NUMBER OF PAGES Vol I-70; Vol II-382

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

NSN 7540-01-280-5500

(The reverse of this page is blank.)

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18

EXECUTIVE SUMMARY

A. OBJECTIVE

The objective of this effort was to develop a portable fire detection and notification system that could be placed aboard parked, unattended large cargo aircraft. The system, referred to as the Aircraft Fire Sentry (AFS), should be light, efficient and easily deployable. Included in the development were phases defining the threats, detection/notification solutions using current commercial hardware, assembly, testing and evaluation of the concepts.

B. BACKGROUND

The system was conceived as a means of protecting national assets, in terms of large-frame cargo aircraft, from damage or catastrophic loss due to fire. Many of today's tanker and cargo aircraft are no longer in production. It is necessary to protect these assets while they still have a useful life. Actual loss of these large aircraft remains low; however, the threat of loss due to fire is always present. All of these aircraft have on-board fire detection and suppression systems to some degree integral with their airframes or powerplants. However, they are only functional when the aircraft is running. The AFS fills the need for fire detection and notification while the aircraft is unattended.

C. SCOPE

The AFS research and development program consisted of five major tasks:

Task 1 -- Feasibility Analysis and Conception Design. This effort included surveys to determine fire protection requirements, literature searches of available technologies that could be adapted for AFS purposes, and the development of conceptual designs that would lead to one or more breadboard systems which could be tested. Cost effectiveness with respect to purchase, installation, operation and maintenance was considered for each configuration.

Task 2 -- System Design and Component Testing. As a result of Task 1, the most desirable AFS configuration was assembled and tested. Results and analyses were reported and recommendations made for a prototype design.

Task 3 -- Prototype Construction, Development, Test and Evaluation. Following a final design review, a prototype AFS was assembled, tested and evaluated.

Task 4 -- Technical Report. This report, a summary of all work completed.

Task 5 -- Draft Performance Description. A draft performance description was prepared describing performance standards for each component of the AFS.

This final technical report is comprised of two volumes. Volume 1 summarizes the entire project. Volume 2 includes the detailed design and testing reports for Tasks 1, 2 and 3, and the Draft Performance Description.

D. METHODOLOGY

Evaluation methodology used to determine preliminary and final designs of the AFS were based on system performance, size, ease of deployment, availability of components and cost. Each of these factors were weighted approximately the same.

Three original concepts were developed after Task 1. Based on the above criteria and two formal design review meetings, the AFS evolved into the prototype unit. Representatives from the Air Force, Applied Research Associates, Inc. and the fire detection/notification industry were in attendance at these design reviews. AFS system requirements were met by open discussion and design of the most responsive, efficiently-sized assembly.

Two actual working models were built and tested -- a small scale "breadboard" design and a "prototype". Based on results from the test on the small scale AFS, improvements were incorporated into the prototype. A final evaluation was made after the prototype test series.

E. TEST DESCRIPTION

Objective test series were conducted on both the small scale and prototype models. These tests included system response times, smoke obscuration and temperature monitoring during live fires, radio frequency quality and distance testing and proper hardware operation. Tests were conducted at Fairchild AFB and at ARA's remote test site (live fires) and laboratory.

F. RESULTS

A working prototype model AFS was provided for Task 3. The result is an assembly that is 14 inches square by 20 inches high, and weight 39 pounds. It is fitted with a single ultraviolet (UV) flame sensor, two wireless remote photoelectric smoke detectors and a manual pull station for initiating alarms. The prototype is self-powered by a 12 VDC battery, and must be fully charged (by AC) prior to deployment. This model meets the requirements of simultaneous fire/smoke stimulus sensing and will report such conditions to the nearest fire department via radio frequency link.

It was documented that this configuration will transmit 1.1 miles while deployed inside an actual aircraft. System response times ranged from instantaneous (flame recognition by UV sensor) to 237 seconds (smoke density increasing at photoelectric detector).

The AFS can be carried by one person and deployed in under 5 minutes. Setup involves bringing it onboard, placing it mid-bay, locating the wireless remote smoke detectors, connecting the system antennas (2) and placing the hard-wired siren/strobe unit outside the aircraft. Once powered on, the AFS will continuously sense for fire conditions until its internal battery power is depleted (36 - 60 hours, depending on conditions and battery size).

G. CONCLUSIONS

The AFS has been demonstrated as a viable, effective means of detecting fires aboard unattended cargo aircraft.

Because of its portable design and ease of deployment, it can also be used in other situations. For example, anywhere a temporary system might be needed, whether it be aircraft, building or tent. The distance between the AFS and the fire department is critical. The proper antenna and/or repeated station(s) must be selected as the situation requires.

H. RECOMMENDATIONS

The AFS system could be produced and used as is. However, the system could benefit from further development in terms of incorporating the latest fire detection hardware and trimming of its overall size and weight. It is also recommended that for any production models, all three types of detection sensors (smoke, heat and flame) be integrated into the system.

(The reverse of this page is blank.)

PREFACE

This report was prepared by Applied Research Associates, Inc., Rocky Mountain Division, Lakewood, Colorado under SETA Contract Number C F08635-88-C-0067, Subtask 3.14.1, for the Air Force Civil Engineering Support Agency (AFCESA), Tyndall AFB, Florida 32403-5319.

The AFCESA Project Officer was Mr. Charles W. Risinger. The period of performance was between 17 August 1990 and 17 August 1992.

This report has been reviewed by the Public Affairs Office and is releasable to the National Technical Information Services (NTIS), at NTIS, it will be available to the public.

The appendices were accepted for publication as submitted by the contractor. This technical report has been reviewed and is approved for publication.

Charles W. Risinger

CHARLES W. RISINGER
Project Officer

Felix T. Uhlik III

FELIX T. UHLIK III, Lt Col, USAF
Chief, Engineering Research Div

Richard N. Vickers

RICHARD N. VICKERS
Chief, Air Base Fire Protection
& Crash Rescue Systems Branch

(The reverse of this page is blank.)

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (concluded)

(The reverse of this page is blank.)

LIST OF FIGURES

LIST OF FIGURES (concluded)

LIST OF TABLES

(The reverse of this page is blank.)

APPENDIX A

FEASIBILITY ANALYSIS & CONCEPTUAL DESIGN

(The reverse of this page is blank.)

AIRCRAFT FIRE SENTRY

"Feasibility Analysis &
Conceptual Design"

Task 1 Report
CDRL Item A024

Prepared by: J. THOMAS CILKE

Applied Research Associates, Inc.
7114 W. Jefferson Ave., Suite 305
Lakewood, Colorado 80235

Date: December 21, 1990

PREPARED FOR HEADQUARTERS AIR FORCE ENGINEERING SERVICES CENTER,
SCIENTIFIC AND ENGINEERING TECHNICAL ASSISTANCE (SETA)
TYNDALL AIR FORCE BASE, FLORIDA 32403

CONTRACT NUMBER F08635-88-C-0067
SUPPLEMENTAL SUPPORT GROUP SUBTASK (SSG) 3.14.1

TABLE OF CONTENTS

Section Page

LIST OF FIGURES

LIST OF TABLES

1.0. INTRODUCTION

The following document describes the results of Task 1, "Feasibility Analysis and Conceptual Design" in accordance with the Statement of Work (SOW) for the Scientific and Engineering Technical Assistance (SETA) Contract Number F08635-88-C-0067, Supplemental Support Group Subtask (SSG) 3.14.1, Aircraft Fire Sentry, paragraph 6.1. This report constitutes the completion of Task 1 and CDRL Item A024.

1.1 Objective

The objective of this project is to develop a portable automatic fire detection and suppression system to protect the cargo bay area of large frame aircraft while they are parked at remote sites on an air base. The system is not designed to replace or diminish the role of the fire department in the fire protection of aircraft. Rather, the system increases the fire department's aircraft fire protection capability by providing early fire detection and notification, and by preventing a fire's propagation within the cargo bay until the fire department can arrive to complete extinguishment.

1.2 Background

Since 1979, over 30 fires have occurred on large frame aircraft (C5, C141, C130, and KC-10) while they were parked on the ground at an Air Force base, causing over 92 million dollars in damage to Air Force property, one death, and several serious injuries (see paragraph 3.2). In many cases the fires went undetected for extended periods of time, or when the fire was detected, the nearby personnel had no means of reporting the fire to the fire department. On most air bases, the reporting of remote fires can only be performed by visual confirmation by personnel using two way voice radios. The long delays between the detection of the fire and the arrival of the fire department left near-by personnel to battle the fire with only hand held and flight line extinguishers resulting in catastrophic loss of the aircraft.

The need for better protection of aircraft against fire threats during war and peace time operations has been a serious concern for many years. In 1984 a basis of need was established by the "Systems Operational Requirements Document," SORD 201-84-I. The document states that there is a significant fire threat for aircraft in the event of an attack on an air base and during post attack recovery. Parked aircraft would be extremely vulnerable to fragment damage and the resulting fire threat. Existing fire departments would not have sufficient resources to adequately protect against and battle all fire threats. In response, a research program was initiated to develop an automatic fire sentry system to help fire fighters guard against these threats.

In almost all of the reported fires, a fire sentry system on board the aircraft could have helped minimize the damage to the aircraft and possibly prevented the one reported death. As presented in Section 3.5, the fire sentry system being developed by

this program enhances a fire department's ability to protect aircraft by providing automatic detection and suppression of fires inside the cargo bay (preventing the propagation of the fire throughout the aircraft), automatic contacting of the fire department, and an additional extinguisher for personnel to use in combating fires.

Along with the serious damages fires have caused, there have been several serious potential fires which caused no reported dollar amount damage to aircraft. These fires were detected not by flame or smoke, but by the residue they left after they self extinguished. Most of these fires occurred inside the fuel tanks and were caused by a static discharge from baffles inside the tanks. Although these fires did not cause any appreciable damage, the possibilities for an explosion or serious fire are great. By providing a means for quickly contacting the fire department and an additional readily available extinguishment source, a fire sentry system could mean the difference between catastrophic loss of an aircraft and a minor mishap.

1.3 Scope

The scope of the Task 1 effort consisted of soliciting product information from vendors of fire detection and suppression equipment for analysis and conceptual design criteria, viewing large frame aircraft which the final system is targeted to protect, and visiting with Air Force fire departments to get their inputs on the system's design. Additional information was obtained from previous reports covering past research performed on the topic of fire protection systems, and from the Environmental Protection Agency (EPA) concerning the impact of fire fighting agents on the environment. Finally, the Boeing Aircraft Company's 737 and 757 assembly plant was visited to observe the fire sentry system used to protect aircraft during final assembly.

The primary focus of this program is to develop a system which will be widely accepted for use. In the past the major focus of fire sentry system research has been on the detection and suppression of fires. These studies show the effectiveness of detectors to recognize fires and suppression systems to put fires out. This program uses the information gained from past research programs to develop a system which meets all the necessary fire extinguishment and false alarm immunity requirements as well as the human interfacing requirements.

2.0. GENERAL INFORMATION

2.1 Firefighting Agents

Historically it is believed that three distinct elements, known as the fire triangle, are required to sustain a fire's combustion: heat, fuel, and oxygen. Extinguishment is performed by removing any one of the three elements from a fire. Carbon Dioxide and dry chemical fire extinguishers limit the oxygen to a fire smothering it. Water quenches a fire by absorbing its heat and cooling the burning fuel. A fire can also be put out by removing the source of fuel (shutting off a gas line) or simply allowing all of its available fuel to be consumed.

During the early part of this century, a family of chemicals known as halons were developed and found to be very effective in putting out fires. However, halons do not put out fires in the traditional sense by removing one of the elements of the fire triangle. Rather, halons extinguish fires by breaking up its uninhibited chemical reaction of combustion.

Halons are a class of hydrocarbons in which one or more hydrogen atoms of a methane molecule (CH_4) have been replaced by either a bromine, chlorine, fluorine, or iodine atom, known as halogens. Halon firefighting agents are identified by atoms which make up their chemical composition. The numbers in the name of the halon agent in order represent the number of carbon, fluorine, chlorine, bromine, and iodine atoms present in each molecule, respectively (trailing zeros are not listed). As an example, Halon 1211 is composed of 1 carbon, 2 fluorine, 1 chlorine, and 1 bromine atom. Other commonly used halon firefighting agents include Halon 1301, and Halon 2401.

It is not clearly understood exactly how halons actually extinguish fires. Several different theories have been developed as to the chemical reaction which takes place when halons are introduced to the flame zone. However, the process of how halons put out fires is not important to this program. What is important is the different types of halon agents which are available and their relative characteristics with respect to other firefighting agents.

2.1.1 Types of Agents

As part of the Task 1 study, an analysis of commonly used firefighting agents were evaluated for possible application to this program. Each agent was evaluated for its effectiveness at putting out aircraft cargo bay fires, availability (both current and future), and cost. Six different types of agents were evaluated: water, foams, dry chemicals, CO2, halons, and halon replacements. Each agent's characteristics and applicability to this program are described in subsequent paragraphs with a summary of all the agents shown in Table A-1.

TABLE A-1. FIREFIGHTING AGENT COMPARISON

	Characteristic	CO2	Halon 1301	Halon 1211	FM-100	FE-25	FE-232
1.	Chemical Formula	CO2	CF3Br	CF2C1Br	CHF2Br	CF3CHF2	CF3CHC12
2.	Molecular Weight	44.01	148.90	165.40	130.90	120.02	152.90
3.	Boiling Point (F)	-109.30	-72.00	24.80	5.00	-55.30	82.20
4.	Liquid Density at 70F (lbs/ft^3)	60.00	98.00	114.00	97.00	78.00	91.15
5.	Vapor Pressure at 70F (psia)	850.00	214.00	36.70	59.00	190.00	13.00
6.	Extinguishing Concentration (%) (1)	34.00	3.50	3.80	3.90	10.10	7.10
7.	Extinguishing Material (lbs) (2)	500.00	200.00	250.00	250.00	550.00	600.00
8.	Agent Cost (3)	$250.00	$1,200.00	$1,625.00	$3,500.00	$9,900.00	$3,900.00
9.	Acute Toxicity (4)	(5) 0.00	800,000	100,000	108,000	>>100,000	32,000
10.	Ozone Depletion Potential	0.00	10.00	3.00	0.19	0.00	0.02
11.	Comparisons						
a.	Clear Vision at Discharge	No	Yes	Yes	Yes	Yes	Yes
b.	Nitrogen Required	No	Yes	Yes	Yes	Yes	Yes
c.	Size of Storage Bottles	40.7 in^3/lb (11.7 ft^3)	24.7 in^3/lb (2.85 ft^3)	21.6 in^3/lb (3.13 ft^3)	N/A	N/A	N/A
d.	Availability of Agent	Many Sources	Limited (6)	Limited (6) AFB Common	New Product Sole Source	-1995	-1991
e.	Toxicity	None	Low	Moderate	Moderate	Moderate	High

NOTES:
(1) N-Heptane, % volume
(2) Assuming 10,000 cubic foot sealed volume -- Quantity of material required to meet recommended concentrations
- a) CO2 34%
- b) Halon 1301 5%
- c) Halon 1211 5%
- d) FM-100 6% (Estimated)
- e) FE-25 15% (Estimated)
- f) FE-232 10% (Estimated)

(3) Assuming wholesale costs
- a) CO2 $0.50 / lbs
- b) Halon 1301 $6.00 / lbs (Not including tax)
- c) Halon 1211 $6.50 / lbs (Not including tax)
- d) FM-100 $14.00 / lbs (Estimated)
- e) FE-25 $18.00 / lbs (Estimated)
- f) FE-232 $6.50 / lbs (Estimated

(4) ALC or LC(50) Rats: 4 hrs-ppm
(5) Although non-toxic, estinguishment concentrations are lethal.
(6) Being phased out. Not available after year 2000.

The first three agents listed, water, foams, and dry chemicals are not being considered for use on this program. Due to the limited geometry (see paragraph 3.4) which agents can be dispersed in a cargo bay (making them very ineffective in suppressing cargo bay fires), the potential damage due to the dispersed agent to the on board cargo and the aircraft, and the resulting clean-up costs make these agents undesirable for use on this program.

The remaining agents CO2, halons, and halon replacement agents each have both positive and negative characteristics which must be weighed before deciding on which final agent to recommend for use on this program. Of the halons, only Halon 1301, Halon 1211, and Halon 2402 are being considered for use. Of the halon replacement agents only FM-100 made by the Great Lakes Chemical corporation, and FE-232 and FE-25 made by the DuPont corporation are currently being considered.

2.1.1.1 Carbon Dioxide

Carbon Dioxide (CO2) is a colorless, odorless, nonconductive gas. It extinguishes fires by reducing the oxygen content in the air to a point where combustion cannot be sustained. CO2 is stored as a liquid. When discharged it produces a dry ice "snow" and a gas with an approximate density of 1.5 times that of air. CO2 is approved for use in the suppression of Class A, B, and C fires Because of its low cooling capacity, the use of CO2 to extinguish deep seated class A fires is limited. Its primary use is for the extinguishment of class B and C fires.

The advantages of CO2 are that it is dry, it does not cause serious damage when discharged, it leaves no residue (eliminating cleanup requirements), it does not deteriorate over time, it is non-corrosive and non-conductive, it is relatively inexpensive, it is readily available world wide, and it does not pose any harmful risk to the environment. The disadvantages to CO2 are that it requires relatively higher concentrations for fire extinguishment which in turn requires greater quantities of agent and larger holding tanks to protect equivalent areas, it produces a lethal atmosphere at the concentrations required to extinguish fires, and it produces a thick cloud making egressing from a discharged area more difficult. If CO2 is used, an egress waiting period (usually between 30 and 60 seconds) must be performed between the detection of a fire and the discharging of the CO2 to allow all occupants of the aircraft to escape.

The NFPA 12A guide recommends a minimum 34% concentration (50% for deep seated fires) of CO2 for total flooding applications. The guide also specifies that 0.050 LBs (0.100 LBs for deep seated fires) of CO2 are required for each cubic foot of volume to attain this concentration assuming no leakage. Table A-1 lists the amount of CO2 required to generate the desired concentration for a sealed (assuming no leakage) 10,000 cubic foot container (comparable to a C141 aircraft).

2.1.1.2 Halons

Halons when discharged produce a colorless gas which provides extinguishment of Class A, B, and C fires. Halon gases are dry, non-corrosive, and

nonconductive. The advantages of using halons are that they are very effective by weight at putting out fires, they do not deplete the oxygen content of the atmosphere, they are mostly low or non-toxic at concentration levels required to put out fires, and they do not generate a total vision obscuring cloud when discharged. The disadvantages of using halons are that they are relatively expensive to recharge after every use (the cost will increase dramatically as production is phased out and an additional tax is added to every pound sold), they are harmful to the environment, by-products of extinguishment are highly toxic, and they will no longer be available for use after the year 2000.

The major differences between the three different Halons under consideration are their chemical makeup. Fluorine atoms tend to increase the stability of the halon while at the same time reduce its toxicity and boiling point. Chlorine and bromine atoms have just the opposite effect by decreasing the halon's stability and increasing its toxicity and boiling point. However, it is the presence of the chlorine and bromine atoms which increase the halon's fire extinguishing effectiveness. Table A-2 gives a comparison of the different characteristics for the candidate halons, and Figure A-1 shows a comparison of extinguishment characteristics.

TABLE A-2. SELECT HALON CHARACTERISTICS

Halon	Formula	Agent Type	Approx. Boiling Temp (F)	Specific Gravity @ 70 F	Lethal Concent. PPM
1301	CF_3Br	Gas	--72	1.57	>800,000
1211	CF_2ClBr	Gas	+25	1.83	~300,000
2402	CF_4Br_2	Liquid	+117	1.17	~126,000

Halon 1301 has the lowest toxicity levels and the highest vapor pressure levels. It is the best halon to use in total flooding applications, especially in locations where personnel may be present during discharge. However, for Halon 1301 to be effective, the fire must be contained in an enclosed area. Halon 1301 applied to external fires tends to dissipate without penetrating the flame zone and therefore has no effect in putting out the fire. Halon 2402 on the other hand as shown in Figure A-1, is the best agent for putting out fires. However, its relatively high boiling point (it is a liquid at most ambient temperatures) makes it a poor agent for total flooding applications. Halon 2402 is also the most toxic of the three halon agents being considered. Because Halon 2402 cannot be used for total flooding applications, it is not being considered for use on this program.

The two halon agents which can be used for total flooding applications, Halon 1301 and Halon 1211, have considerably different operating characteristics. The following describes some of the pro and cons of using Halon 1301

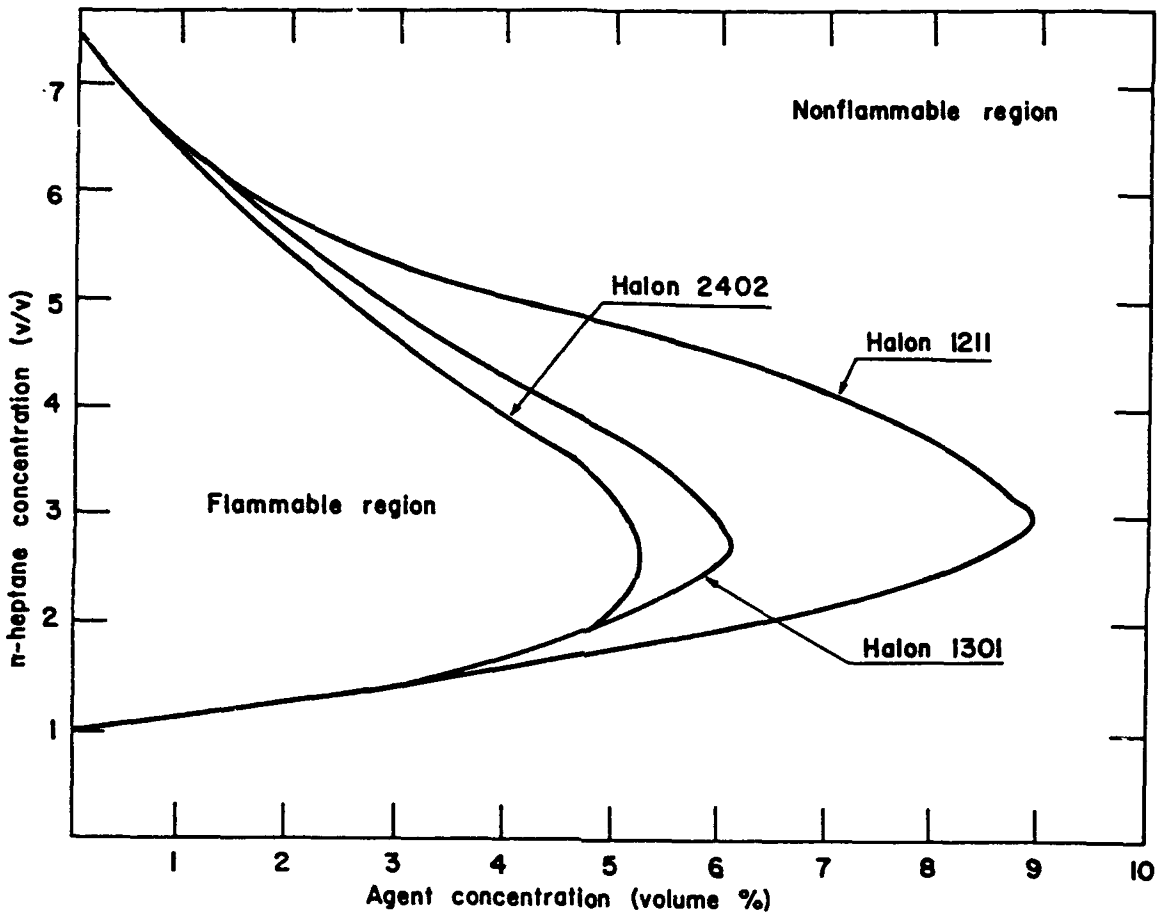


Figure A-1. Comparison of Halon Extinguishment Characteristics

versus Halon 1211. Halon 1211 is the primary fire fighting agent used in Air Force base flight line fire extinguishers. Air Force fire departments are familiar with its uses and hazards, and the agent is in general readily available on most Air Force bases. Halon 1301 on the other hand is used in the protection of C5 cargo bays and avionics areas. Air Force fire departments are familiar with its uses and hazards, but the agent is not as readily available on most Air Force bases. Because Halon 1301 vaporizes so quickly, its fire fighting effectiveness is reduced to a greater extent by openings (causing agent leakage) to the outside. However, when the aircraft is completely sealed Halon 1301 is more effective in penetrating and attacking fires in all areas (including nooks and crannies). Halon 1301 is also a better overall fire fighting agent and is less toxic. Environmentally, Halon 1301 has a higher Ozone Depletion Potential (ODP) than Halon 1211. However, both agents due to their high ODPs are being phased out. Finally, most research in trying to develop alternate agents for the Halons has been focused towards finding a Halon 1211 replacement. Systems based on using Halon 1211 are more likely to have a replacement agent available sooner. However, no drop-in replacement agent is currently available for either agent.

As previously mentioned, CO2 and Halon 1301 are the agents most commonly used for total flooding applications. In comparing the use of CO2 versus Halon 1301, the Kidde-Fenwal Corporation recommends the following. If extensive discharge testing is going to be performed, or if the system is going to be used to protect areas where a limited number of personnel work with easy egress, or if the area contains materials which may react with halons a system utilizing CO2 is recommended. If personnel egress is limited a system utilizing Halon 1301 is recommended.

CO2 systems cost less to install, operate, and maintain. CO2 is inert producing no agent breakdown that is toxic or reacts with other materials. CO2 is readily available throughout the world, is cheaper, and does not require an additional nitrogen supercharge to discharge. Halon 1301 on the other hand requires fewer number and smaller cylinders for storage, and does not require personnel egress prior to discharge allowing it to begin extinguishment sooner (although personnel egress is required as soon as the agent is discharged). Other considerations include the fact that Halon 1301 dissipates slower than CO2 making it easier to maintain desired concentration levels and provides better protection against deep seated fires. Both agents, however, have been used successfully and effectively in a number of different total flooding applications protecting a wide range of hazards.

2.1.1.3 Replacement Agents

The final types of agents being considered for use on this program are the replacement agents for Halon 1301 and Halon 1211. Two types of replacement agents are being considered. The first type is a direct drop-in replacement for either agent. The second type is an agent which has similar operating and firefighting characteristics as Halon 1301 or Halon 1211 but may require some modifications to existing extinguishment systems or a totally redesigned extinguishment system. The availability of a direct drop-in replacement means that the fire sentry system could be

designed around one of the halon agents and switch over to the replacement agent once it becomes available. Using the second type of agent requires that the extinguishment system be designed around the replacement agent and possibly use one of the halon agents until the replacement agent becomes available.

Two companies as well as several government and university agencies are actively trying to develop replacement agents for Halon 1301 and Halon 1211. The Great Lakes Chemical Corporation has developed a product which is currently available for limited use, called FM-100, which has physical characteristics somewhere between Halon 1301 and Halon 1211 and an ODP within the acceptable limits set by the EPA. However, its lethal toxicity level is worse than Halon 1211 making it only usable in normally non-occupied areas. Initial tests of FM-100 have shown that its fire fighting characteristics require approximately 0.5% higher concentrations to extinguish a fire as compared to Halons 1301 and 1211.

The DuPont Corporation is developing products to replace both Halon 1301 (FE-25) and Halon 1211 (FE-232). However, these products are still undergoing developmental testing, evaluation, and characterization, and are not going to be available for use until the later part of this decade. Although, FE-232 is being marketed as a possible replacement agent for Halon 1201, its high boiling temperature and low vapor pressure indicate that it is a liquid when discharged which makes it completely unsuitable for use as a total flooding agent and is not being considered for use on this program.

The demand for replacement agents is a direct result of the Montreal Protocol and the Clean Air Act of 1990. The details of these legislations and their impacts on the use of halons is described in Section 2.2. The status as to how soon these agents are going to be available is described in next section.

2.1.2 Halon Replacement Agent Status

Two major recent events, the signing of the Montreal Protocol and the enactment of Clean Air Act of 1990 (see paragraph 2.2) have paved the way for all substances which deplete or cause damage to the atmospheric ozone layer to be phased out. This includes all the popular halon fire fighting agents, especially Halon 1301 and Halon 1211, currently used in wide spread commercial and military applications. In response to these directives several companies and government agencies have initiated research programs to find alternative replacement agents for Halon 1301 and Halon 1211. The Halon Alternative Research Corporation (HARC) headed by Dr. Jack Riley of Ansul, and supported by a number of diverse companies including Great Lakes Chemical Corporation, DuPont, Ansul, Fike, British Petroleum, and MCI Communications, as well as the EPA and the United States Department of Defense is a new organization with an estimated $25 million dollar budget over the next eleven years to develop and facilitate the introduction of new fire fighting agents. Other agencies including New Mexico Engineering Research Institute (NMERI), National Institute of Standards and Technology (NIST), Wright-Patterson AFB, and AFESC at Tyndall AFB are also working on developing new agents.

As an additional incentive to develop new replacement agents, a new excise tax was imposed on all which depleted the ozone layer. The amount of the tax was directly related to the ozone depletion potential (ODP) of the material. As shown in Table A-1, Halon 1301 has an ODP value of 10.0, Halon 1211 has a value of 2.0, and Halon 2402 has a value of 6.0. The tax is equal to $0.25 per pound beginning January 1, 1991 through December 31, 1992. Beginning January 1, 1994 the tax jumps to $1.65 times the agent's ODP per pound, and increases by $0.45 per year. In the year 1999 the tax on Halon 1301 will be $49.00 per pound. This along with the diminishing supplies due to the phasing out of the agents and the increasing demand for halon products is driving the cost of recharging halon systems increasingly upward.

While the Great Lakes Chemical Corporation has announced that its FM-100 has acquired the EPA's approval for use in normally non-occupied areas, the agent is not a direct drop-in replacement for either Halon 1301 or Halon 1211. Manufacturers of elastomers (o-rings, gaskets, synthetic rubber, etc.) have found their products exhibit linear swelling characteristics when exposed to FM-100. Being so new, long term effects, operating characteristics, recommended usages, availability, cost, and uniform standards have not been established.

As previously mentioned, DuPont is in the process of developing replacement agents for Halon 1301 and Halon 1211. The replacement agent for Halon 1211, FE-232, is being developed as a substitute to be used instead of Halon 1211 during Air Force fire fighting training exercises. It is designed to have similar physical characteristics as Halon 1211 but does not have to be as effective at fighting fires. Much higher concentrations of FE-232 are required than Halon 1211 to extinguish similar types of fires. Combustion testing of this product is currently being performed at NMERI. Preliminary tests for FE-232 have shown that it has a much higher toxicity, and a much lower ODP (0.02) than Halon 1211. While compatibility tests have not been completed, FE-232 has strong solvency characteristics and causes certain synthetic rubbers to swell excessively. This agent is not expected to be available until 1991, and then only in small quantities.

FE-25, a replacement agent for Halon 1301, is currently undergoing characterization testing. Preliminary tests have shown that FE-25 is not as effective in fighting fires as Halon 1301, requiring as much as three times the concentration to extinguish equivalent test fires. Toxicity information on FE-25 is still inconclusive with further tests still to be performed. Initial compatibility tests have shown that FE-25 is compatible with certain types of gasket materials making drop-in replacement possibilities more likely. Availability of FE-25 is not expected until 1995 with costs approximately three times that of Halon 1301.

The Air Force's time table for finding a drop-in replacement agent for Halon 1211 is expected to last until the later part of this decade. An agent using FE-232 blended with another agent is currently undergoing toxicity and characterization testing. This agent should be available during the later part of FY93 for training use only. A final replacement agent is not expected to be developed until FY94 with

additional 2 to 3 years of toxicity and characterization testing before it is available for operational use. There is currently no time table for finding a drop-in replacement agent for Halon 1301. Some small dry bay testing of a Halon 1301 replacement is being performed at Wright-Patterson AFB. Again, a greater emphasis has been placed on finding a replacement agent for Halon 1211 because of its extensive use in flight line extinguishers.

2.2 Montreal Protocol / Clean Air Act of 1990

In Montreal in September 1987, 24 nations, including the United States, signed an agreement to reduce and eventually eliminate the use of chlorofluorocarbons (CFCs) and halons which deplete the earth's ozone layer. This agreement known as the Montreal Protocol was signed by eight additional countries by June 1988. The agreement was further strengthened when in June 1990 the Montreal Protocol was revised and now supported by 93 countries. The new agreement set the stage to phase out CFCs and halons and restrict other ozone-depleters by the year 2000. With respect to halons, the agreement set to reduce halons by 50% by 1995 with complete phaseout by 2000. This includes Halon 1301, Halon 1211, and Halon 2402. However, exemptions for essential uses is permitted. Beginning in 1991 a committee of "international experts" (still to be determined) shall convene and determine which products or systems deserve exemption from the Protocol's provisions. Final decision from the committee is expected in 1991. It is expected that very few products or systems shall be given exemption status.

Near the end of 1990, the United States passed a bill called the Clean Air Act of 1990, which strengthened the provisions of the Montreal Protocol by requiring a complete phase out of CFCs and halons by 2000. A major impact of the bill is the accelerated phasing out of halon agents The bill besides banning the production and distribution of halons after the year 2000, also imposes a tax per pound sold based on the agent's ozone depletion potential (ODP). Halon 1301 has the highest ODP of 10.0 and would be taxed the greatest followed by Halon 2402 with an ODP of 6.0 and Halon 1211 with an ODP of 2.0. Only those halon or related agents with an ODP of less than 0.2 are allowed after 2000.

The term phasing out refers only to the new production of the agents. Existing system are still allowed to use halon agents and may be recharged after use. However, the agent used to recharge the system must come from reserve banks or be transferred from another system. The focus of the legislation is to force people to be more careful with and more aware of the consequences of using halon fire fighting agents until suitable replacement agents can be found. A study of 1986 uses showed that by weight, less than 40% of the halon agents discharged went towards fighting fires while over 60% were what are termed controllable emissions. Controllable emissions are those caused by testing, training, accidental discharges, and system servicing.

2.3 Impacts

The impact of the Montreal Protocol and the Clean Air Act of 1990 is causing serious consequences in the fire fighting industry. In 1985 it was estimated that approximately 1.7 million portable systems utilizing Halon 1211 and 86 thousand total flooding systems utilizing Halon 1301 were used by commercial agencies. The Department of Defense, especially the Navy and the Air Force, use extensive numbers of halon fire fighting systems for the protection of aircraft and ships. Being so effective at fighting fires with no reasonable alternative agent available or expected to be produced in the near future, the demand for halon systems is increasing.

The first major impact of the Montreal Protocol is that the cost of using or recharging a halon system is increasing due to increased demand, decreased supplies, and added taxes. Users of halon systems without an adequate replacement agent may not be able to recharge their systems after use, leaving once protected areas vulnerable to fire damage. They are forced to switch over to other agents such as CO2, dry chemicals, or water. However, these require complete replacement of the existing system once used for halon, and the acceptance of the detrimental characteristics of the replacement agents. Due to incompatibilities with halons, switching over to the one replacement agent which is currently available, still requires a complete redesign of the extinguishment system. Commercial industries as well as military applications are worried that they may not be able to suitably protect against fire hazards when the Protocol's full provisions take effect.

While many commercial industries as well as government agencies have, in response to the protocol, been trying to develop acceptable replacement agents, the long term characteristics of these agents will not be known for many years. Ever since their initial development in the 1940s, extensive research has been conducted on determining the characteristics, long term effects, optimal extinguishment equipment, and system standards for the modern day halon agents. While a company may proclaim that it has developed a replacement agent which exhibits similar fire fighting characteristics as one of the existing halons, an extreme amount of testing still needs to be performed to fully characterize the new agent.

Testing that will have to be performed on each new agent includes determining a new agent's throwing distance, dispersion characteristics over temperature, its ability and concentration levels required to fight various types of fires, impact on flame fronts, residual chemical breakdowns, toxicity of the agent and its after fire residues, stability of the agent over time, corrosive affects of the agent and its byproducts on various types of materials, environmental impacts, long term health effects, as well as many other characteristics. The list of unknown attributes for each new agent is very long. It is not known when an agent is submitted for testing whether or not it will sufficiently pass all tests to be widely accepted for use as a replacement agent. A single imperfection may cause an otherwise perfect agent to be rejected for use. In short, without a single replacement agent for Halon 1301, 1211, or 2402 currently available or soon to be available, the risks and resulting consequences of completely eliminating these agents

is quite severe. Additionally, the costs for fully testing the new replacement agents can be expected to be very high and eventually passed on to the end users.

The impacts to this program are that a decision must be made :- which agent the system will be designed around. The initial choice is to use one of the halon agents (Halon 1301). Their operating characteristics and fire fighting capabilities are well suited for this application and are far superior to any other agent available. However, the system can only be designed around an existing halon agent if it is assumed that either a drop-in replacement agent will become available before the existing agent can no longer be used, or the system or the agent will be exempted from the provisions of the Montreal Protocol and the Clean Air Act (even at the cost of additional high taxes and reduced production). Neither scenario is very likely.

The second choice is to design the system around one of the up and coming halon replacement agents. But, designing the system around a new agent is also very risky. First of all, there are very few (only 1 to date) new agents in which to design a system around with very few others available in the near future. Secondly, in the event that an attribute of the new agent is discovered which makes it undesirable for use, the system would have to be redesigned to accommodate a different agent (which may not exist).

Finally, the system could be designed around CO2 accepting the safety risks involved in the event of an accidental or purposeful discharge. Again, other agents such as water, dry chemicals, or foams are not being considered due to their clean up costs and their potential damage to the cargo and the aircraft. The preliminary decision as to which agent the system shall be designed around is discussed in paragraph 4.0.

In making the decision as to which agent to use, it should be noted that the fire sentry system is in a conceptual design phase. The focus of the program is dedicated towards designing an improved fire detection and communication system rather than on proving it is possible to extinguish fires in a cargo bay. Analyses and tests showing how good all of the perspective agents (except for the replacement agents) are at extinguishing fires and what equipment is needed to achieve desired extinguishment levels of agent have already been performed. It is intended that the design of the extinguishing system shall be based on existing data. Also, it is not within the scope of this program to test or verify the characteristics of a new agent. Finally, in keeping with the provisions of the Montreal Protocol and the Clean Air Act of 1990, it is not recommended nor politically desired to use a halon fire fighting agent to prove out the operation of the system. Once conceptually proven, the system can be easily retrofitted to use any fire fighting agent.

3.0. BACKGROUND AND REQUIREMENTS

The following paragraphs form the basis from which the preliminary fire sentry system was designed. One of the requirements for completing Task 1 of this program was to perform a survey to determine the fire protection requirements of parked large frame aircraft, and a survey to determine the availability of current technologies to accomplish the required protection.

To determine the protection requirements of large frame cargo aircraft, four Air Force bases (Norton, Travis, March, and McCord) were visited to view representative aircraft and discuss the requirements of the system with the corresponding base fire departments. The information from the Air Force bases was incorporated along with data from accident reports on past military and commercial fire events to derive the final requirements.

3.1 Types of Aircraft Reviewed

Four different types of large frame cargo aircraft were reviewed at the various Air Force bases. A C141 aircraft was viewed at Norton AFB and McCord AFB, a KC-10 and a C130 were viewed at March AFB, and a C5 was viewed at Travis AFB. Figures A-2 through A-5 show the exterior and the interior cargo holds of each of the aircraft respectively. Particular facets of each aircraft were observed to determine their possible effects on the design of the fire sentry system. These included the size of the cargo bay, the number and sizes of openings into the cargo bay, available equipment which could be used, available places in which to install the fire sentry system, the types and sizes of cargo carried, how the cargo might impede the installation or removal of the fire sentry system and how the fire sentry system might impede the installation or removal of cargo.

The C141's cargo bay is approximately 100 feet long, 9 feet wide, and 9 feet tall (to the center beam, 12 feet to the ceiling). The volume of the bay is approximately 11,000 cubic feet and can hold approximately 8630 cubic feet of cargo. The C141 has 4 emergency personnel escape hatches. Two are located just in front of where the wing attaches to the fuselage on both sides of the aircraft, and two are located near the rear of the cargo bay again on both sides of the aircraft. The doors are approximately 2 feet by 3 feet in size and are easily removed by a single crewman from inside or outside of the aircraft. The C141 also has two vents from the outside of the aircraft to the cargo bay. The fuselage vent is a 1 5/8" hole and the cryogenic vent is a 3/4" hole. Both holes are located approximately five feet from the front of the cargo bay on either side of the aircraft. The only other openings from the cargo bay to the outside are 3 crew doors, one located at the front and the other two located at the rear of the cargo bay, and the cargo bay door itself.

The KC-10's cargo bay is approximately 120 feet long, 20 feet wide, and 10 feet tall (in the shape of a half circle). The volume of the bay is approximately 18,000 cubic

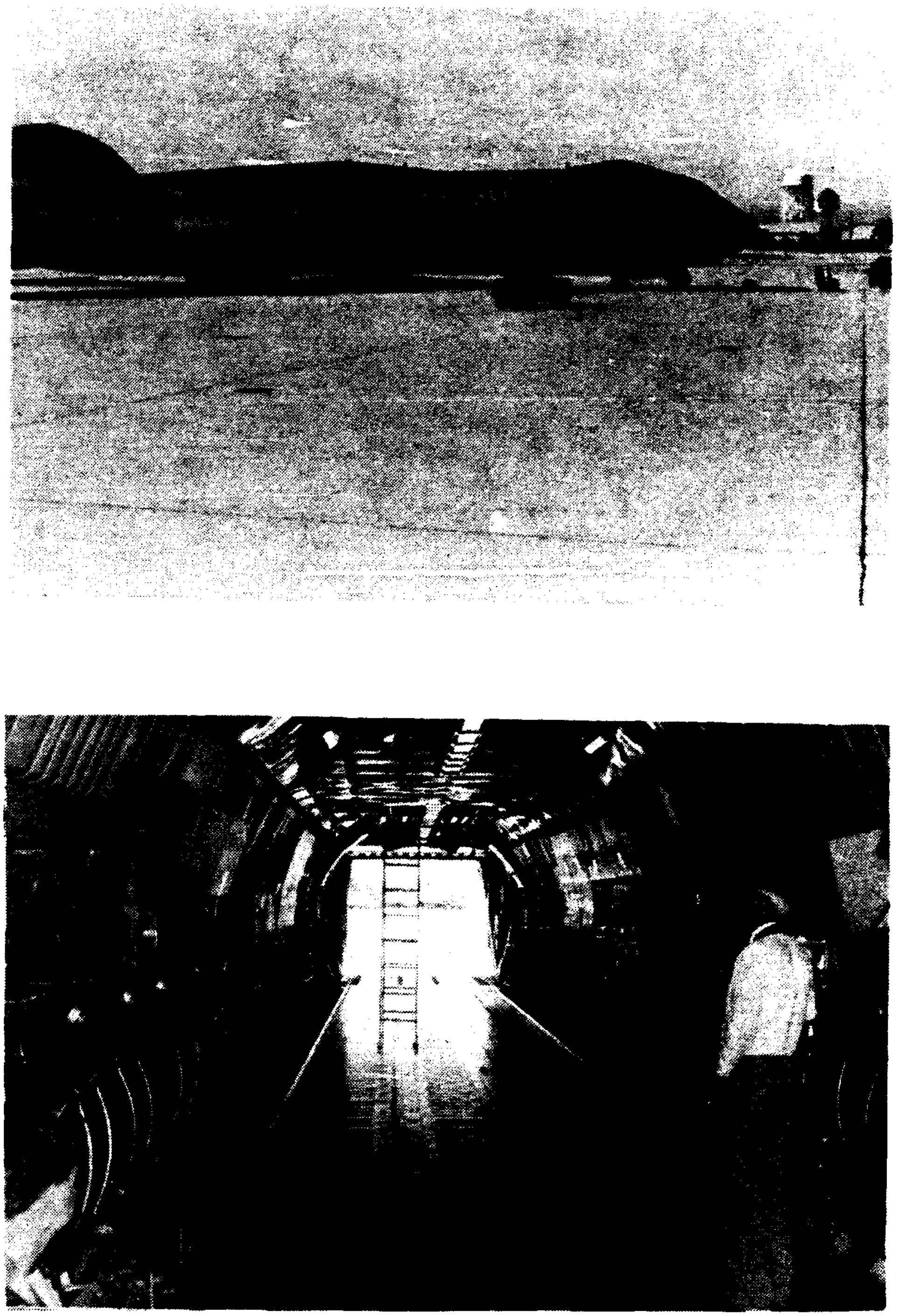


Figure A-2. C141

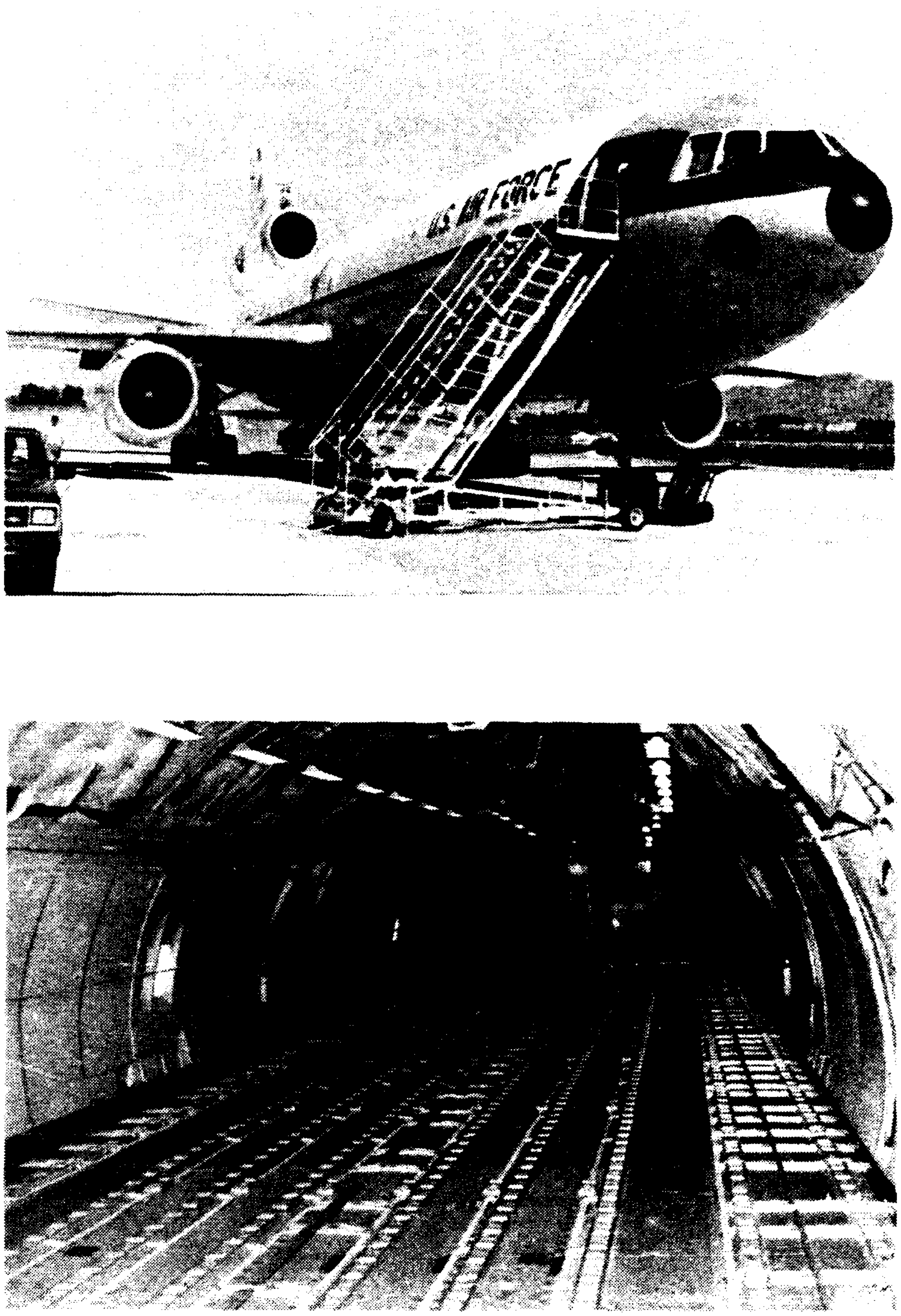


Figure A-3. KC-10

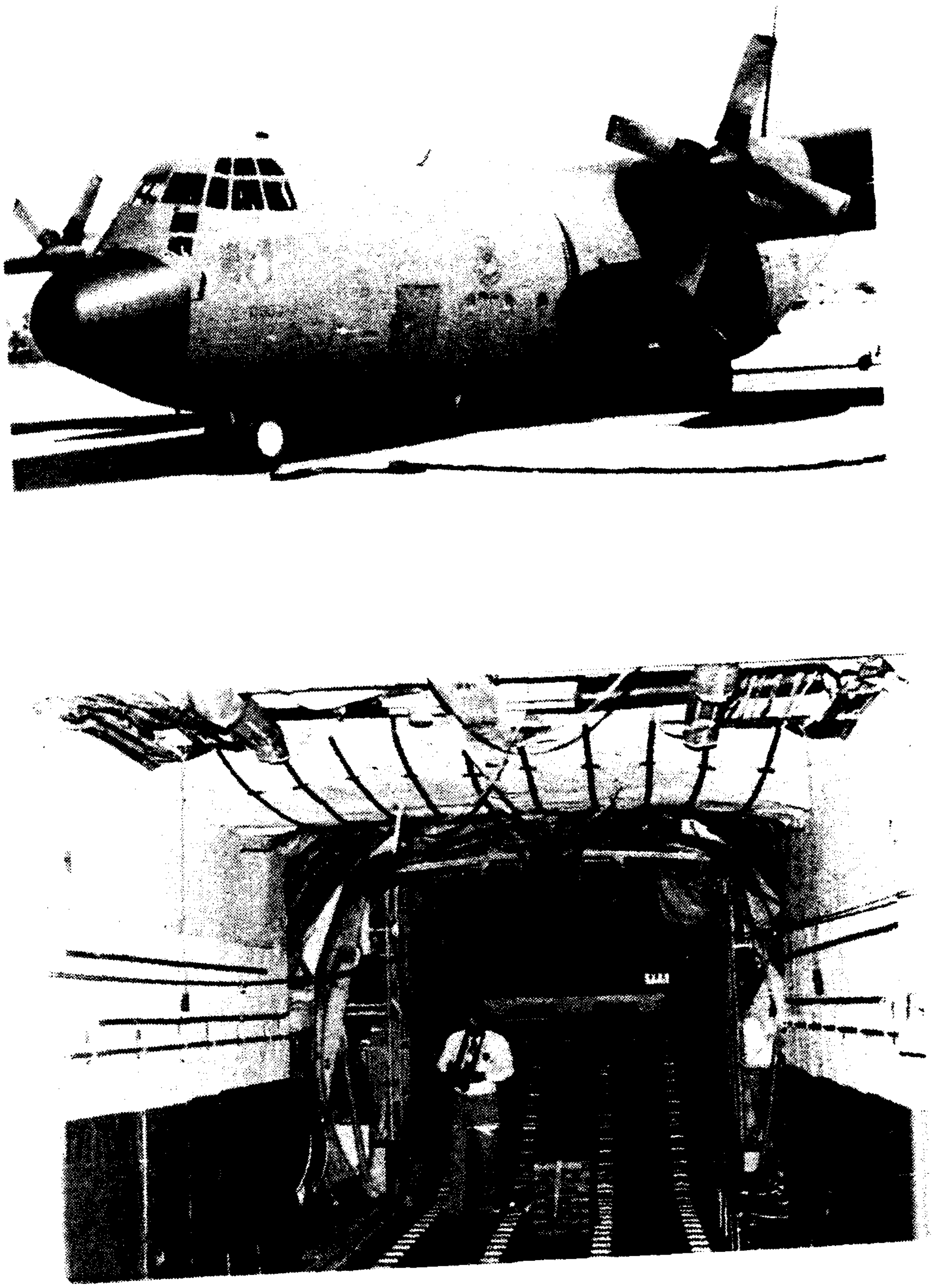


Figure A-4. C130

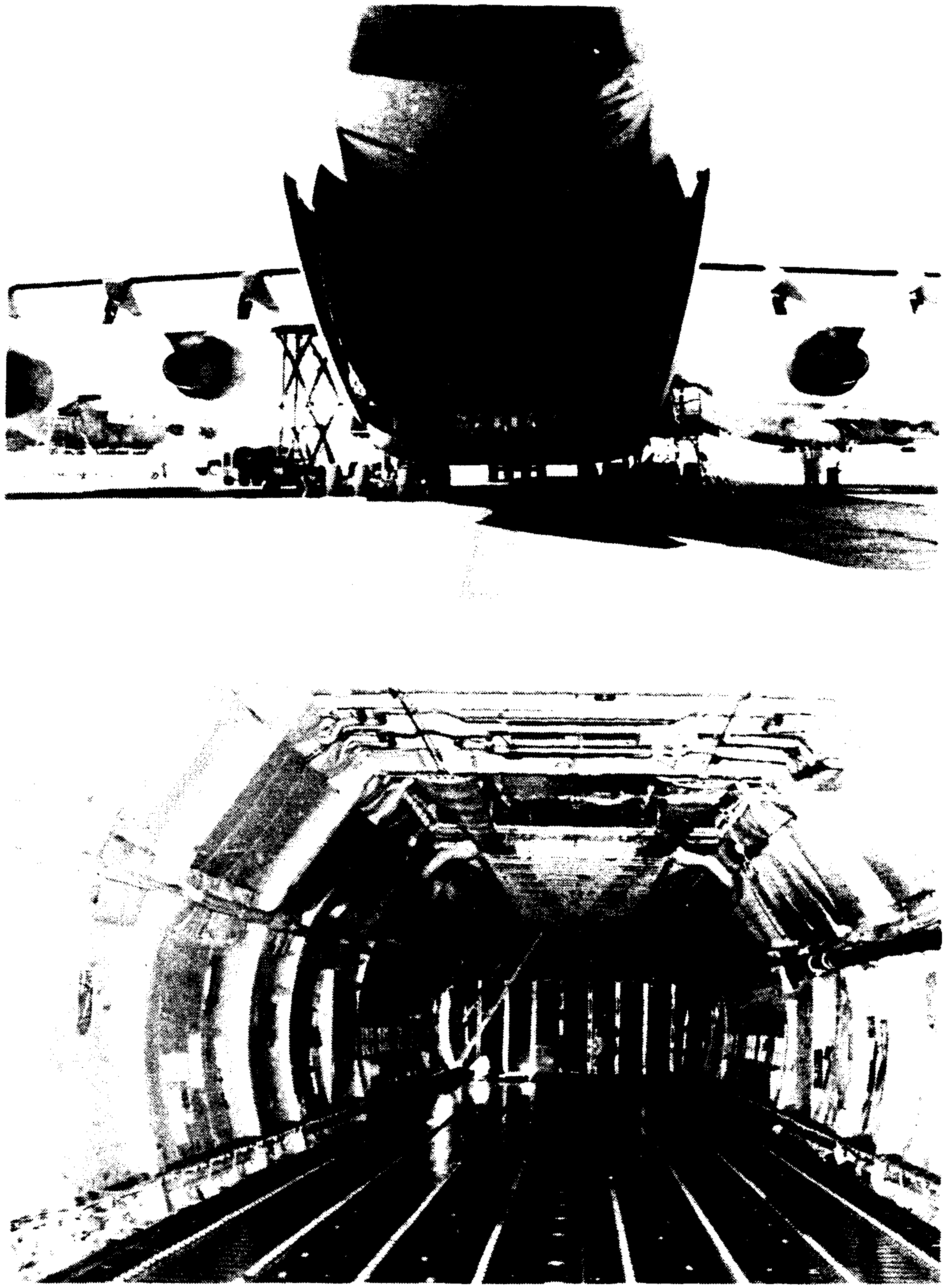


Figure A-5. C5

feet and can hold approximately 11,000 cubic feet of cargo. The KC-10 has a single emergency exit from the cargo bay located near the rear of the aircraft. The exit is not easily opened for general non-emergency use. The cargo bay has a single personnel access hatch located in the floor in the middle of the bay on the right side of the plane. This hatch leads to a space under the floor which is accessible from the outside of the aircraft. The KC-10 has a single vent (overboard vent) located just over the wing on the left side of the aircraft. The only other accesses to the cargo bay are the passenger door through the passenger compartment and the cargo bay door. Of all the aircraft viewed, the KC-10 has the fewest accessible openings from the cargo bay to the outside and provides the greatest challenge to the extinguishment design of the Aircraft Fire Sentry system.

The C130's cargo bay is approximately 50 feet long, 12 feet wide, and 10 feet tall. The volume of the bay is approximately 6,000 cubic feet and can hold approximately 4,500 cubic feet of cargo. The C130 has a single emergency escape hatch on the right side of the aircraft and two escape hatches on the top of the aircraft (one in the cockpit and one over the cargo door). The C130 has no vents and the only other openings to the cargo bay are the main crew door and the cargo bay door.

The C5's cargo bay is approximately 125 feet long, 24 feet wide, and 14 feet tall. The volume of the bay is approximately 50,000 cubic feet and can hold approximately 34,800 cubic feet of cargo. The aircraft also has two crew decks which are located above the cargo bay. The C5 has four 3" circular openings from the cargo bay into the side wheel wells. The openings are covered with a clear plastic lens. The openings are not accessible for use due to an obstruction by the landing gear in each of the wheel wells. The C5 also has a single 4" circular opening from the cargo bay to the outside near the front of the cargo bay. However, this opening is used to drain a portable toilet and may not always be available for use by the Fire Sentry system. The C5 has 2 emergency escape hatches located near the cargo bay door on either side of the aircraft. The only other openings to the cargo bay are the main crew door, the rear cargo bay door and the front cargo bay door.

All of the aircraft viewed had some sort of fire detection system on board. The C141, KC-10, and the C130 used smoke detectors located in the ceiling of the cargo bay. The C5 used both smoke and UV flame detectors. The C5 was the only aircraft to have an active fire suppression system consisting of ten 70 pound Halon 1301 bottles. The bottles are discharged automatically or manually from the cockpit. In all the aircraft, the status of the detectors is displayed on a panel in the cockpit. However, if the airplane is not powered, the detectors, and in the case of the C5 the halon extinguishing system, cannot operate. In all the aircraft, hand held halon 1211 fire extinguishers are distributed throughout the cargo bay and a 150 pound Halon 1211 flight line extinguisher is positioned outside.

3.2 Past Fire Events

Since 1980, over 50 ground related fires have been reported to have occurred on C141, C130, KC-10, and C5 type aircraft with a total damage of over 92 million dollars. Table A-3 lists the fire events which were reported. In almost all of the fire events, the aircraft was being operated with personnel nearby. In almost all of the events the fire sentry system being developed under this program could have helped minimized the damage caused by the fire.

While most of the reported fire events did not start in the cargo bay, the potential for an accidental cargo related fire is very real. In the commercial aviation world there have been a number of reported fires which originated in cargo hold of aircraft. Table A-4 is a sample list of past fire events which have occurred on commercial aircraft.

3.3 Fire Threats

The most common sources of fires aboard military aircraft are caused by the engines, the aircraft power units, and during fuel transfer operations. Other possible sources of ignition include electric motors, power supplies, batteries, avionic electronics, personnel heaters, tools, loaded cargo, and lightning. Fire threats located outside the cargo bay area are not addressed by this program except to the extent that they may cause a fire which may burn through to the cargo bay.

Located inside the cargo bay of all the aircraft viewed are a number of different materials which are flammable or can add to a fire's intensity. The most serious threats are the hydraulic, oxygen, and fuel lines which are located overhead or along the walls of the aircraft. The severing of any one of these lines causing a leak can generate the necessary conditions for a serious fire or an explosion. Other potential fire threats include batteries, exposed power lines, and electronic systems.

The cargo loaded onto the aircraft also poses a serious fire threat. The cargo transported by military aircraft ranges anywhere from non-flammable materials, personnel luggage, building materials, chemicals and fuels, to very highly explosive ordnances and ammunition. While most cargo is very carefully packaged (as evidenced by the limited number of reported cargo related fires aboard aircraft), the potential for a fire is great. This can be seen from the number and causes of cargo fires which have occurred aboard commercial aircraft. In many cases fires were triggered by shifting cargo (or luggage) which caused improperly packaged or restricted materials to ignite. In the span of one year alone, 5 fires caused by matches igniting were reported. Other causes of reported fires include reactions due to leaking chemicals, spontaneous ignition of stored chemicals, overheating motors, and combustible materials coming in contact with normally hot surfaces.

To determine the characteristics of fires occurring in large cargo bays the Federal Aviation Administration (FAA) conducted several studies in the early 1980s. The studies concluded that the larger a cargo bay is, the higher the rate of temperature

TABLE A-3. PAST MILITARY CARGO AIRCRAFT FIRE EVENTS

Number	Aircraft Type	Property Damage Reported	Personnel Damage Reported	Injuries	Fire Damage	Personnel Present	Help From Fire Sentry Alarm	Detection	Suppression Internal	Suppression External
1	KC010A	$48,277,639	$47,000	Death	Fuselage Midsection	Yes	X	X	X	X
2	C130H	$17,380,000			Flight Deck	Yes	X	X	X	X
3	C141B	$11,333,270			Aircraft Destroyed	Yes	X	X	X	X
4	C005A	$9,091,986	$2,916		Troop Compartment	Yes	X	X	X	X
5	C005A	$4,919,214			Wing & Engine	No				
6	C005A	$173,306			Engine	Yes	X		X	
7	C130E	$169,209	$11,830	Burns	Fuel Tank	Yes	X	X	X	X
8	C005A	$114,185			Refueling Vehicle	Yes	X			X
9	C005A	$98,000			Engine	Yes	X			X
10	C005A	$65,797			Cargo Bay Area	Yes	X	X	X	
11	C130E	$55,459			Engine	Yes				
12	EC130H	$50,103			Engine	Yes	X			X
13	HC130H	$43,060	$10,080	Fire Burns	Pylon Tank	Yes	X			X
14	C130C	$35,152			External Fuel Tanks	No				
15	C141A	$33,227			Engine	Yes	X			X
16	EC130H	$29,600			Engine	Yes	X			X
17	AC130A	$26,570			Fuel Filler	Yes				
18	C130E	$19,836			* Fuel Tanks	No				
19	C130E	$18,227			GTC Area	Yes	X	X	X	
20	C130E	$17,722			Main Fuel Tank	Yes	X	X	X	X
21	C130E	$15,050			Main Fuel Tank	Yes	X			X
22	C005A	$13,918			Engine	Yes	X			X
23	HC130P	$11,569			External Fuel Tanks	Yes	X	X	X	
24	C005A	$8,687			Engine	Yes	X			X
25	C130E	$8,560			* Fuel Tanks	No				
26	HC130H	$7,450			Fuel Tank	Yes	X			X
27	C130B	$6,748			* Fuel Tank	No				
28	AC130	$5,782			Prop De-Icing System	Yes	X			
29	HC130P	$4,439			External Fuel Tanks	Yes	X	X	X	X
30	WC135B	$2,638			Generator	Yes	X	X	X	
31	C141B	$2,096			APU	Yes	X			X
32	C141A	$2,075			LOX Service	Yes	X			
33	C130E	$1,347			* Main Fuel Tank	No				
34	C141B	$0			Refueling Vehicle	Yes	X			X
35	C130E	$0			* Aux Fuel Tank	No				
36	HC130P	$0			* Fuel Tank	Yes				
37	C130H	$0			* Main Fuel Tank	No				
38	C005A	$0			Engine	Yes	X			X
39	C130E	$0			* Main Fuel Tanks	No				
40	C005A	$0			Engine Oil Sply Line	Yes	X			
41	C005A	$0			APU	Yes	X			X
42	C130	$0			Dry Bay	Yes	X	X	X	
43	C130E	$0			* Fuel Tanks	No				
44	C141B	$0			Engine	Yes	X			X
45	C130E	$0			* Main Fuel Tank	No				
46	C130E	$0			* Main Fuel Tank	No				
47	HC130P	$0			* Fuel Tanks	No				
48	C130A	$0			Engine Compartment	Yes	X			X
49	WC130H	$0			Ext Vent Valve	Yes	X			
50	C130A	$0	$1,950		Oxy Service Trailer	Yes	X			
51	C005A	$0			Heater	Yes	X	X	X	
52	C130E	$0			Prop Anti-Ice System	Yes	X			X
53	C130E	$0			* External Fuel Tank	No				
54	WC130H	$0			* Benson Tanks	No				
55	C141B	$0			Refueling Vehicle	Yes	X			
56	C130E	$0			* Aux Fuel Tank	No				
		$92,041,921	$73,776							

TABLE A-4. SAMPLE LIST OF PAST COMMERCIAL FIRE EVENTS 1971-1980

1. A fire occurred in the AFT cargo compartment of a Boeing 707. Cause of the fire was undetermined but assumed to originate from spontaneous ignition of stored chemicals.

2. Smoke generated by the exothermic chemical reaction between leaking nitric acid cargo and the sawdust packing around it, caused the crew to lose control of a 707 cargo aircraft. The aircraft was destroyed in a crash.

3. Fires in the cargo bays of a Boeing 727 and a DC-9 were caused by burning mail bags.

4. Matches igniting in luggage were the cause of fires on three BAC 1-11-500s

5. Shifting cargo leaning up against a door light caused sufficient smoke to set off alarms in a Gulfstream G159.

rise and maximum ambient temperature a fire can produce. The studies showed that a fire could produce temperatures as high as 1700°F at the ceiling height within 2-3 minutes unless the airflow to the fire was shut off. Reducing or shutting off the air flow within the cargo bay greatly reduces a fire's intensity and the overall problem of suppression. Although flaming can be suppressed by sealing the cargo bay, fires in a smoldering condition can burn for an indefinite period of time and re-ignite as long as 30 minutes later if air flow is restored, even slightly. Leakage rates as low as one air change per hour can cause a fire's re-ignition. The use of an extinguishing agent at the time of a fire's detection was shown to greatly reduce the occurrence of flash fires and minimize the temperatures in the bay.

From these tests it is apparent that the C5 poses the greatest fire threat followed by the KC-10, C141, and the C130. The KC-10 poses the additional threat due to its refueling tanker configuration. Also the fire threat is the greatest during periods when cargo bays are loaded and the cargo bay door is open. In all cases whether or not the cargo bay is full or empty or if any doors to the cargo bay are open or closed, it is very important that a means exist to rapidly detect fires and disperse an extinguishing agent. For flash fires the importance of an automatic suppressant release is especially crucial.

Another indirect fire threat to military aircraft is the inability to automatically notify the fire department in the event of a fire. Currently on air bases the only means of detecting and reporting fires is by local personnel visually confirming a fire and reporting it using portable radios. This problem is compounded by the fact that most personnel do not carry a portable radio with them at all times. In several instances of reported fires aboard military aircraft, fires were reported not by the personnel at the fire but rather by personnel who just happened to be passing by.

When the fire department receives a call, it must rely on the verbal information given to determine the location of the fire. It must then go to the designated area and begin searching for the fire by looking for smoke, flames, or crewman to guide them. On a large airfield with many parked aircraft this is not always easily performed in an expeditious manner, especially at night. The additional delay imposed by limited communications and locator methods increases the time for a fire to gain intensity and potentially grow into an uncontrollable disaster.

3.4 Fire Protection of Large-Frame Aircraft

When designing a fire sentry system for large-frame aircraft, two different scenarios must be considered. First of all the fire sentry system must address and provide protection against as many fire threats as possible. Secondly, the fire sentry system must address the operational characteristics of the aircraft it is to protect.

The operation of the fire sentry system is broken up into two distinct parts: fire detection and fire suppression. The fire detection operation deals with the methods which fires are detected, the physical configuration of the detection system, and any communication links required. The fire suppression operation deals with the type of fire

suppressant used and the configuration of the equipment used to deliver the agent. For both operations the criteria which must be considered include: are personnel around or is the aircraft unattended, is the cargo bay empty or fully loaded, and are any doors (especially the cargo bay door) open?

The detection operation of the fire sentry system is required to operate under a number of different constraints. First the detection system must be able to "see" or detect a fire when a plane is fully loaded with cargo (which act as obstructions). This relates to the geometry of the detection system and the type of detectors used. In order to be effective, the detection system must be able to detect the presence of a fire quickly while at the same time not respond to the large number of false alarm stimuli present in and around an aircraft.

As previously mentioned, the quicker the detection system can accurately detect a fire, notify the fire department, and release a suppressing agent the less damage the aircraft is likely to sustain. The detection system must be modular in design so that it can be used in any large frame aircraft, it must be easily installed and removed, and it must be capable of rejecting all types of false alarm stimuli.

To meet the detection constraints, detector modules utilizing several different types of detectors are used. The different detectors used monitor the presence of unique fire characteristics. As a minimum, both flame and smoke detectors shall be used. The use of different detectors increases the probability of early detection and with the use of intelligent processing of the data provided by the detectors, minimizes the false alarming. Paragraph 3.6 summarizes the different types of detectors available, their operational characteristics, and their range of typical use.

The detection system is also required to address the problem of communication links required to operate the system. One link is required to notify the fire department of an existing fire and clearly direct them to the fire's location. A second link is required to transfer the data from each of the detector modules to the external cart for processing. Due to the remote nature of where aircraft are parked on airfields, the only communication available is through an RF link. This presents a problem in that while most Air Force bases do not have automatic fire detection systems using remote communication links, some Air Force bases do have or are in the process of installing one. This leads to a compatibility problem if the fire sentry system is widely deployed. The communication between the detector modules inside the aircraft and the external cart can be either hard wired or RF. If RF communication links are used the problem of interference between nearby systems must be addressed.

The fire suppression system is also required to operate under a number of constraints. The system must be easily installed and removed, it must be compatible to all aircraft with as few alterations as possible, it must not interfere with normal cargo loading and unloading operations, and it must not require any permanent modifications to the aircraft. Several options were discussed to meet these criteria. Placing the bottles storing the suppressant agent inside the cargo bay was rejected due to the quantity of agent required to suppress a fire (especially in a C5) which by their physical

size and weight would get in the way. The system must use existing openings or doors in which to transfer the suppressant agent from the external cart to the interior cargo bay. All aircraft have large cargo doors, personnel access doors, and escape hatches. While all the aircraft viewed have some sort of fuselage vent, the physical characteristics of the vents are so widely different that no single agent dispersion system could be used for all aircraft. Any hoses running into the aircraft must be hung from the ceiling so as to not interfere with normal cargo loading operations.

Because of the geometry of a cargo bay and obstructions generated by the different types of loaded cargo, a total flooding application of the fire suppressant agent must be used. Given this requirement, selection of the exact type of agent depends on a number of different factors. Toxicity of many agents at extinguishment concentrations require a delay period between a fire's detection and the dispersion of the agent to allow personnel within the cargo bay to safely egress. Each agent has a different dispersion characteristic which is affected by openings to the cargo bay. Those agents which have high dispersion characteristics (CO2 and Halon 1301) used for total flooding applications, require proportionally greater quantities at higher rates to be discharged to maintain the necessary extinguishment concentrations due to leakage from the cargo bay. In the case of all the aircraft viewed, especially the C5, the opening of the cargo bay door almost totally diminishes the effectiveness of the suppressant agent to penetrate the flame zone and fight a fire. However, for a sealed bay the high dispersion agents have the advantage requiring fewer numbers of discharge ports to achieve the necessary concentrations throughout any part of the cargo bay.

Other agents which are not normally used for total flooding applications (Halon 1211 & FM-100) require several dispersion nozzles along the length of the cargo bay to ensure full coverage. Because these agents have relatively high boiling temperatures, they have a problem of puddling or condensing when discharged. Special care must be taken to insure adequate mixing with air to provide a uniform dispersion of the agent.

The final area of concern is to insure that administrative controls on the system are maintained. This means that when the system is deployed, a series of administrative checks must be established to verify that the system is being used, is being used properly, and is being maintained. Without these administrative checks in place the likelihood of abuse of the system is very high. When deployed, the system represents an additional piece of equipment that the ground crews are required to be trained on, maintain, and install and remove from each aircraft on a frequent basis. During the visit to the Boeing Company's 737 and 757 assembly facility it was observed that many of the fire sentry systems used to protect the aircraft during assembly were not properly installed or were not operational. Even with the threat of employees losing their jobs, it was pointed out that administrative controls still have to be continuously monitored and enforced.

When protecting anything by an automatic fire protection system, it is far better not have the system installed than to rely on an improperly installed or broken system. In order for a fire protection system to be effective it must be designed such that it is

reliable and personnel will want to use it. The equipment must be viewed as having its benefits far outweighing any inconveniences.

3.5 Operational Requirements

After viewing the various large frame aircraft, visiting with several different Air Force fire departments and ground crews, and reviewing previous work in this area, the following is a list of minimal general requirements that the fire sentry system developed for this program should meet.

1. The system must be designed knowing that it is going to be used by air crewman and fire fighters on any flight line throughout the world. Personnel using the equipment may be wearing gloves, fire fighting gear, or chemical warfare gear. Size, weight, shape, and appearance are all critical factors which must be addressed.

2. The system and all of its components must be rugged, capable of withstanding extreme abuse and mishandling. All components must meet military standards for shock, vibration, temperature, pressure, adverse weather, humidity, fungus, hazardous atmospheres, EMI, and reliability, etc.

3. The system must be easily assembled, installed, removed, and disassembled. Installation or removal of the system should not take more than 2 trained personnel working only a few minutes regardless of the aircraft or the cargo loaded.

4. The system must be modular in design such that it can be used to protect any large frame aircraft.

5. The system must have a low false alarm rate and a high detection rate.

6. The system must provide automatic alarm notification to the fire station via an RF communication link. System must also provide audible and visual alarms to alert nearby personnel.

7. The system and all of its components must operate off of rechargeable batteries and must be capable of continuous operation without a recharge for a minimum of 72 hours.

8. System must not interfere with normal aircraft activities (primarily the loading and unloading of cargo) and must not require any permanent modification to the aircraft.

9. System must use commercially available or Air Force base common components wherever possible.

10. System must be capable of suppressing Class A, B, and C fires by maintaining required agent concentration levels in all areas of the cargo bay for a minimum of 5 minutes with all non-emergency access doors except cargo bay doors fully open.

11. System must include built in testing capabilities to verify the operational status of the system before each use and during normal operations to aid in the trouble shooting and repair of an out-of-order system.

12. The detection system and the suppression system must be operationally independent from one another. That is each system must be able to operate without the use of the other. The suppression system shall be activated either manually or by an electronic signal from the detection system.

3.6 Industry Research

As part of the requirements for completing the Task 1 effort of this program, an industry research was performed to determine the availability of equipment which could be used on this program. The main areas of the research were focused around detector and detection systems, extinguishment systems, and communication systems. Of the systems and components investigated, almost all are designed to be used in commercial or industrial applications, primarily for the protection of rooms in an office building. Because of the special nature of the fire sentry system, the use of any components found require some customizing to be used on this program. Additional research still has to be conducted to determine if any military qualified components exist.

3.6.1 Fire Detectors

Fire detection is performed by measuring by-products generated by a fire or the changes in the environment caused by a fire. Detectors, in general, measure or "look for" only one particular characteristic of a fire. The different characteristics primarily measured by detectors are smoke, infrared radiation (IR), ultraviolet (UV) radiation, and temperature. Other detectors are available but not as commonly used. When the characteristic exceeds a predetermined threshold, then the detector outputs a signal indicating it has detected a fire. Unfortunately, most commercially available detectors are easily fooled and respond to non fire related stimuli. Detectors also require continuous maintenance. Improperly maintained detectors can cause false readings including not "seeing" an actual fire. Fire detection is based on the premise that characteristics of a fire are not normally present in the detection area, and when a characteristic appears, it must be caused or generated by a fire. Almost all fire detectors are based on this erroneous premise and as a result are highly susceptible to false alarming.

The detection of smoke is primarily performed by two different methods: ionization and photoelectric. An ionization smoke detector uses a piece of radioactive

material to ionize the air in a chamber making it conductive. Electrodes are used to monitor the current across the chamber. Smoke particles entering the chamber reduce the conductance of the air, and when the conductance drops below a threshold level, the detector outputs an alarm signal.

Two different types of photoelectric smoke detectors are available. Both use a light source and a photosensitive device to detect the light. One type of sensor has the light source always incident on the photodetector. Smoke passing between the light source and the photodetector reduces the light incident on the photodetector. The other sensor relies on the smoke to reflect the light on to the photodetector. In both cases when the amount of light incident on the photodetector reaches a threshold, the detector outputs an alarm.

Both types of smoke detectors are fooled by the same types of false alarm stimuli. Smoke (like from a diesel engine), fog, high humidity, or dust can cause the detectors to alarm. Ionization detectors are also susceptible to false alarming due to RF and voltage transients. From the manufacturer's catalogs most of the smoke detectors, both ionization and photoelectric, had limited temperature operating ranges (32^{O} to 100^{O}F) The photoelectric detectors have the advantage that the smoke does not actually have to come in contact with the detector elements and therefore the detector electronics can be more easily protected.

While most smoke detectors can only measure incident smoke which happens to enter the smoke chamber (spot detection), some detectors come with fans or sampling tubes to bring the smoke to the detector. These detectors are more efficient in detecting fires at greater distances. However, because of the fan, they also require more power to operate.

Flame detectors measure the radiant energy emanating from a burning substance. The two types of flame detectors used measure either infrared (IR) or ultraviolet (UV) radiation. IR detectors operate by measuring the intensity and changes in the incident infrared energy usually in a very narrow frequency range. Most IR detectors have built in logic to only respond to changes which occur in the 1 to 10Hz frequency range which is characteristic of a flickering flame. This helps prevent false alarming by rejecting static or fast modulating blackbody radiation which may be present. IR detectors are easily false alarmed by anything which creates a modulating IR radiation including sunlight reflecting off shimmering water, strobing lights, or personnel working in close proximity to the detector. IR detectors are also very sensitive to variations in operating temperatures.

UV detectors operate by measuring the intensity of incident UV radiation and output a signal proportional to the intensity. UV detectors are very sensitive and will false alarm very easily in the presence of any UV energy including arc welding, certain type of lights, and radioactive materials, even if the source of the UV energy is far removed from the detector. The operation of the UV detector is degraded by the presence of UV absorbing materials including oil mists or films developing on the viewing lens.

Both types of flame detectors can see and quickly detect most hydrocarbon fires. Because of the limited frequency band which each sensor operates, UV detectors are not sensitive to IR energy and vice versa. False alarm stimuli for both types of detectors is commonly present in and around the cargo bays of military aircraft. To help minimize the false alarming, a third type of flame detector which uses both UV and IR detectors is available. Because UV and IR detectors have virtually no common false alarm sources, when used together produce a detector with an overall lower false alarm rate.

UV and IR detectors can only detect fires which are in the field of view of the sensing elements. This allows the detectors to "see" fires at a distance. However, any obstructions in the field of view minimize the area covered by the detector. This is of considerable concern if these types of detectors are used in a completely filled cargo bay.

The final type of fire detectors being considered for use on this program are heat sensing devices. As was demonstrated by FAA tests, there is a significant heat rise within a cargo bay in the event of a fire. Two different types are commonly used. The first type, known as a fixed temperature detector, responds when the ambient reaches a predetermined level. The second type, known as rate-of-rise detectors, respond when the rate at which the temperature is changing (rising) exceeds a threshold. These sensors have the distinct advantage that they have a very low false alarm rate. Normal activities within a cargo bay or variations due to normal weather patterns cannot generate temperatures or temperature deviations within the range of these sensors. The disadvantages of these sensors are they only measure temperatures in a very small area (spot measurement) and they are slow to respond.

Along with the detectors, controllers are required to provide the necessary support electronics to operate the detectors and associated decision making processors to help minimize false alarming. One of the most commonly used decision techniques is called detector voting where two or more detectors are required to "see" a fire before an alarm is sounded. This helps prevent false alarming by ignoring spurious stimuli detected by individual detectors. Other techniques include adding time delays to require a fire signal to be present for a minimum specified time before an alarm is sounded. A list of manufacturers of detection equipment is shown in Table A-5.

TABLE A-5. MANUFACTURERS OF FIRE DETECTION DEVICES

Manufacturer	Types of Detectors					Other Equipment	
	Smoke	IR	UV	UV/IR	Heat	Control	Alarms
Ansul	X					X	X
Armtech				X			
Detector Elec.		X	X	X		X	
Fenwall	X				X	X	
Fike	X					X	X
Fire Lite	X				X	X	X
Fire Sentry			X	X		X	
Gamewell	X	X			X	X	X
Notifier	X				X	X	X
Pyrotronics	X	X	X		X	X	X
Scientific Instr.			X				
Spectronics	X				X	X	X
Walter-Kidde	X				X	X	X

3.6.2 Fire Extinguishment Systems

There are many different methods and agents used in fire extinguishing systems. Typical extinguishing systems use either water, foams, dry chemicals, halons, or CO2. Systems using any of the prospective replacement agents are not yet available or have had any of their operational characteristics defined. The extinguishing requirements for the Aircraft Fire Sentry system are that it must be effective against A (ordinary flammables, paper, and wood), B (flammable liquids), and C (electrical) fires, it must not require extensive cleanup effort, and it must not cause damage to the aircraft or the loaded cargo. This eliminates all extinguishing systems except those which use either halons or CO2 as agents. The final requirement is that the design of the system need not ensure complete extinguishment, rather it need only to contain or suppress a fire until the fire department can respond to complete extinguishment.

From the industry research several companies were found to manufacture total flooding Halon 1301 and CO2 systems. Halon 1211 is considered by industry to be a streaming agent not used for total flooding applications. As such only wheeled or hand held portable Halon 1211 extinguishers could be found. Table A-6 lists companies which manufacture extinguishing systems.

TABLE A-6. EXTINGUISHING SYSTEM MANUFACTURERS

Manufacturer	Halon 1211	Halon 1301	CO2
Ansul		X	X
Amerex	X	X	X
Fenwall		X	
Fike		X	
Pyrotronics		X	
Uptime		X	
Walter Kidde		X	X

3.6.3 Communication Systems

Because the fire sentry system is going to be used on aircraft parked remotely on air base ramps, the problem of how to transmit an alarm signal to the fire station arises. The obvious solution is to transmit the alarm signal over an RF link using portable radios. An industry research was conducted as to what equipment was available to perform the communication between the fire sentry system and the fire house, and between fire sentry system and the detection modules. The two different types of communication equipment looked at were microwave, FM, VHF, and UHF links.

The type of communication system used depends on a number of different factors. Further investigation is needed to determine the regulations governing the operation of communication equipment on a military base especially on the flight line of an Air Force base. Topics including available frequencies, power output, modulation techniques, and communication protocols must still be resolved. The conceptual design of the fire sentry system plans on serial digital data transmissions for all of its communication links transmitted using FM radios. Table A-7 lists manufactures of communication systems being considered for this program.

TABLE A-7. POSSIBLE COMMUNICATION SYSTEMS

Manufacturer	Communication System
General Electric	DL-100 Transceiver
Johnson	3410 Telemetry Modules 3420 Telemetry Modules 3490 Telemetry Modules
Monaco	RFM 500 Modem, Connects to D-500 system
Motorola	Radius
Remtron	RTS Telemetry System
Vectran	VR-11 Transceiver VR-30 Modem

4.0. FIRE SENTRY CONCEPTUAL DESIGN

To satisfy the requirements necessary to protect against existing fire threats and meet the fire protection and operational criteria using existing equipment wherever possible the following preliminary designs were devised. The designs are broken up into three main pieces: internal detection, internal suppression system, and the external cart.

The first major obstacle to overcome with the design was how to communicate between the internal detector modules and the external cart, and how to transfer the agent from the external cart to the cargo bay without interfering with normal aircraft activities. Several ideas were initially discussed. The first set of ideas centered around placing all of the suppressant agent bottles and the master processing station inside the cargo bay in various different configurations. This was rejected because it would always be in the way whenever cargo was loaded or removed. The next idea was to put the agent bottles and the master processing station outside on a cart and bring the agent into cargo bay through hoses through a normally open door. This idea was rejected because it would get in the way and it prevented the closing of the door. The next idea was to use "holes" or openings in the fuselage to inject the agent. However, not all the aircraft viewed had similar types or easily accessible openings, and the openings which were available were too small to disperse sufficient agent to extinguish a fire.

The only other openings which are not normally used during ground operations are the emergency exit doors. It was decided that these doors provided the best access into the cargo bay. To install the system, the existing emergency door is removed, set aside, and replaced by another door designed for aircraft fire sentry system. The new door provides the necessary openings into the aircraft, is easily installed and removed, does not require a modification to the aircraft, is easily modified to fit any aircraft, is out of the way of any normal aircraft activities, and can still be used as an emergency exit if necessary. All connections between the external cart and the cargo bay are made through the door. The door also has a overpressure blowout disk to prevent accidental damage to the aircraft in the event that the cargo bay is completely sealed at the time of discharge.

A block diagram of the proposed system is shown in Figure A-6. The system consists of the detection modules and extinguisher nozzles inside the cargo bay, the new door, and the external cart.

Three different detector module designs and two different agent dispersion designs are being proposed. The first detector module design is shown in Figure A-7. Each detector module consists of a small sealed enclosure approximately 8" to 12" on a side. Four UV/IR flame detectors are mounted orthogonally on the four sides; a photoelectric smoke detector is mounted on the top along with a heat detector (optional). A small fan is used to draw air through the smoke detector to increase its sensitivity. The system is installed in the cargo bay by hanging from either the walls or

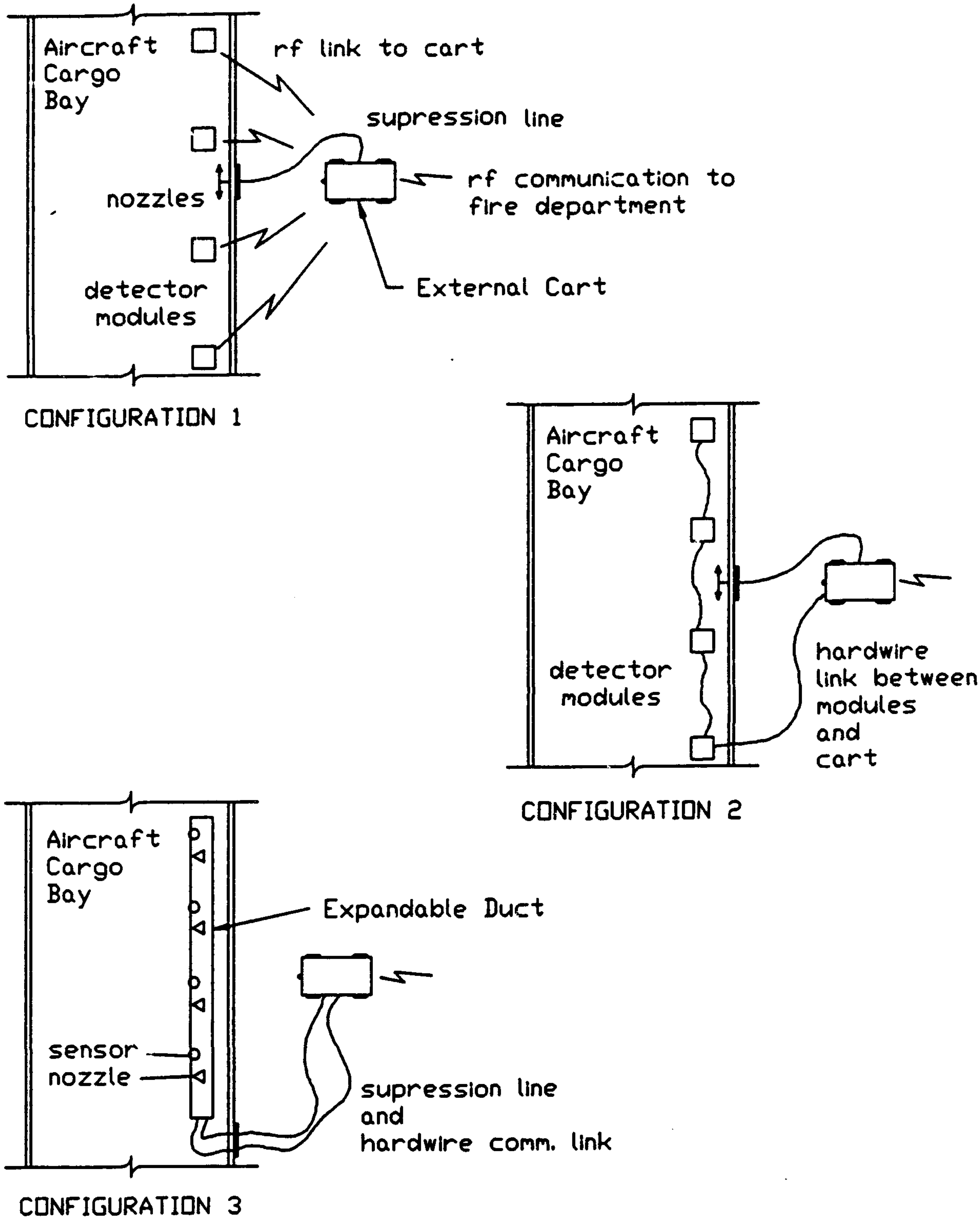
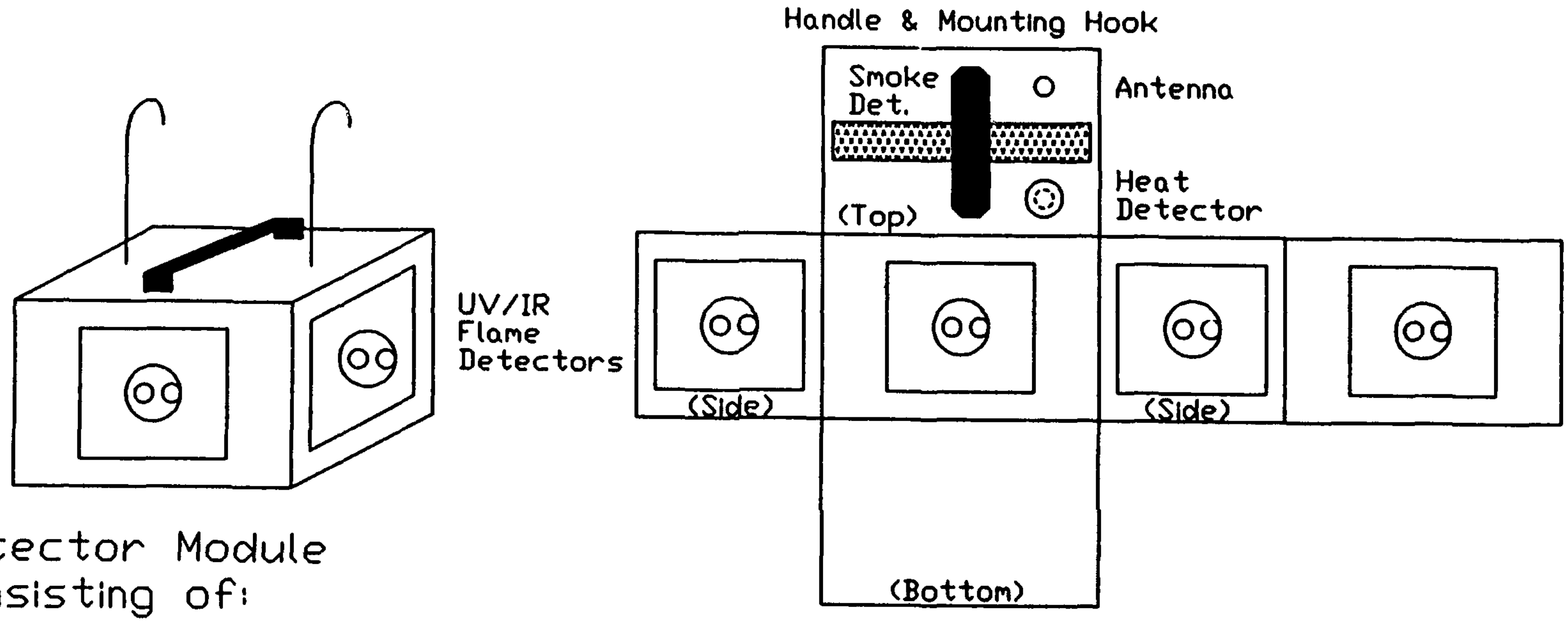


Figure A-6. Block Diagram of Proposed System



Detector Module
Consisting of:
1. 3 - UV/IR Flame Detectors
2. 1 - Smoke Detector
3. 1 - Battery (internal)
4. 1 - Tx/Rx FM Communication link
5. 1 - Antenna
6. 1 - Heat Detector

Figure A-7. Preliminary Detector Module Design

the ceiling, or setting it in a place where the detectors have an unobstructed view of the bay. The outputs of the sensors are digitally encoded and transmitted to the external cart upon request. The power of the transmitter would be approximately 1 milliwatt with a maximum range of 300 feet. The module is powered up with a rechargeable battery. The detector modules perform no processing except the encoding of the data. The external cart shall request updates from each detector module a minimum of 1 to 10 times a second. The system is flexible in design such that any number of detector modules can be installed in an aircraft. It is anticipated that 4 modules are required for a C5, C141, and KC-10, and two modules for a C130.

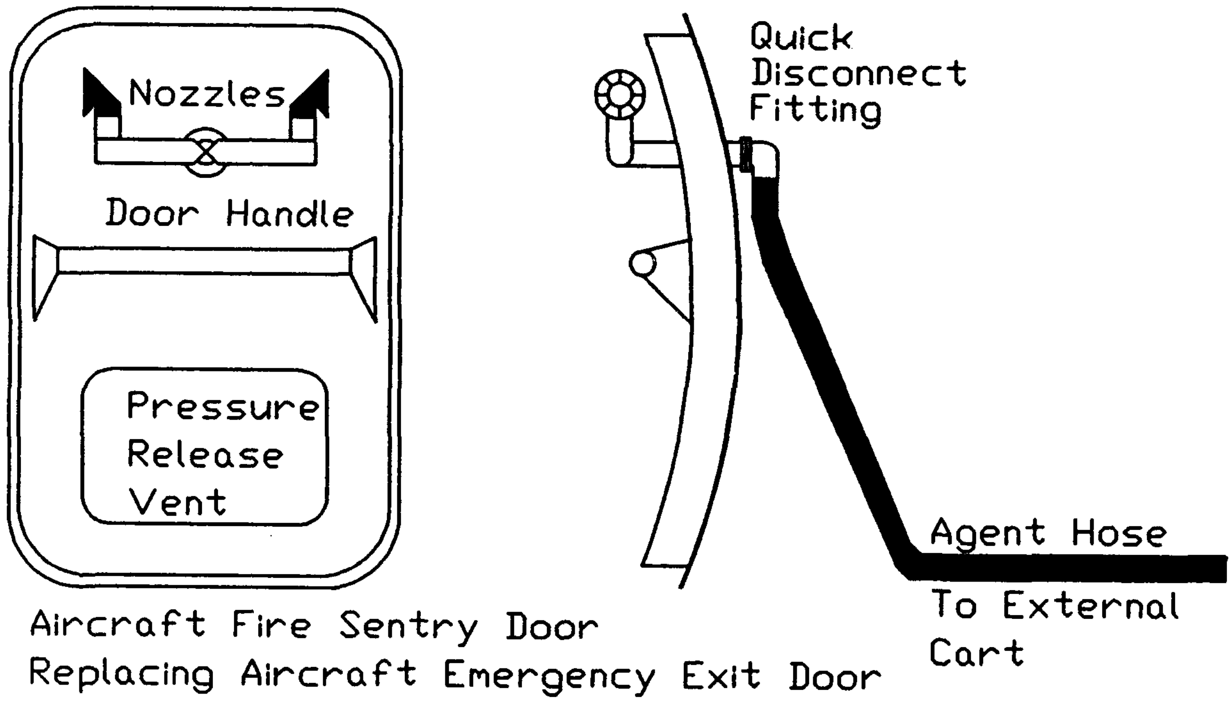
The second detector module proposed has exactly the same configuration as the first module except that all power and communication is provided through a hard wire link. (That is the connecting cabie) which might at times get in the way. This reduces the flexibility of where the modules can be placed. The modules are designed to either be daisy chained together or connected directly to the door.

The first agent dispersion system shown in Figure A-8 has a single set of nozzles attached to the door. This system can only be used if the suppressant agent has sufficient dispersion characteristics to completely fill the cargo bay from a limited number of nozzles (Halon 1301 and CO2). A single pipe with several nozzles would be permanently attached to the inside of the door. The suppression system would be installed by simply attaching a flexible hose from the external cart to a quick release connector on the outside of the door.

The third detection module and the second agent dispersion system are incorporated together into a single expandable module. This system is used when it is necessary to provide additional nozzles spread out along the length of the cargo bay to disperse the agent. The combination module is shown in Figure A-9. For the combination module both the agent hose and the detectors are mounted inside a light weight protective housing. The housing protects both the detectors and the nozzles from accidental damage. Several nozzles are mounted along the length of the hose. Each end of the hose is fitted with a self sealing quick release connector. Several different types (UV/IR, smoke, and heat) of detectors are also mounted along the length of the module. The detectors have overlapping fields of view such that a fire anywhere in the bay is seen by two or more detectors. Modules are connected together in series to expand and provide the necessary protection for any aircraft. Once all the modules are connected together, the entire assembly is connected to the ceiling of the aircraft. Connection to the door is made through the use of a flexible hose and cable.

Of the systems described, the combination module is the most cumbersome to use. However, it provides greatest agent dispersion capability which is of great importance for agents which are not normally used for total flooding applications.

The final part of the Fire Sentry design is the external cart. The external cart is responsible for storing all of the extinguishment agent and providing all the processing of the detector data, the necessary communication links between the detector modules and between the fire station, and visual and audible alarms. A conceptual design of the



Figur_ A-8. Preliminary Dispersion System Design

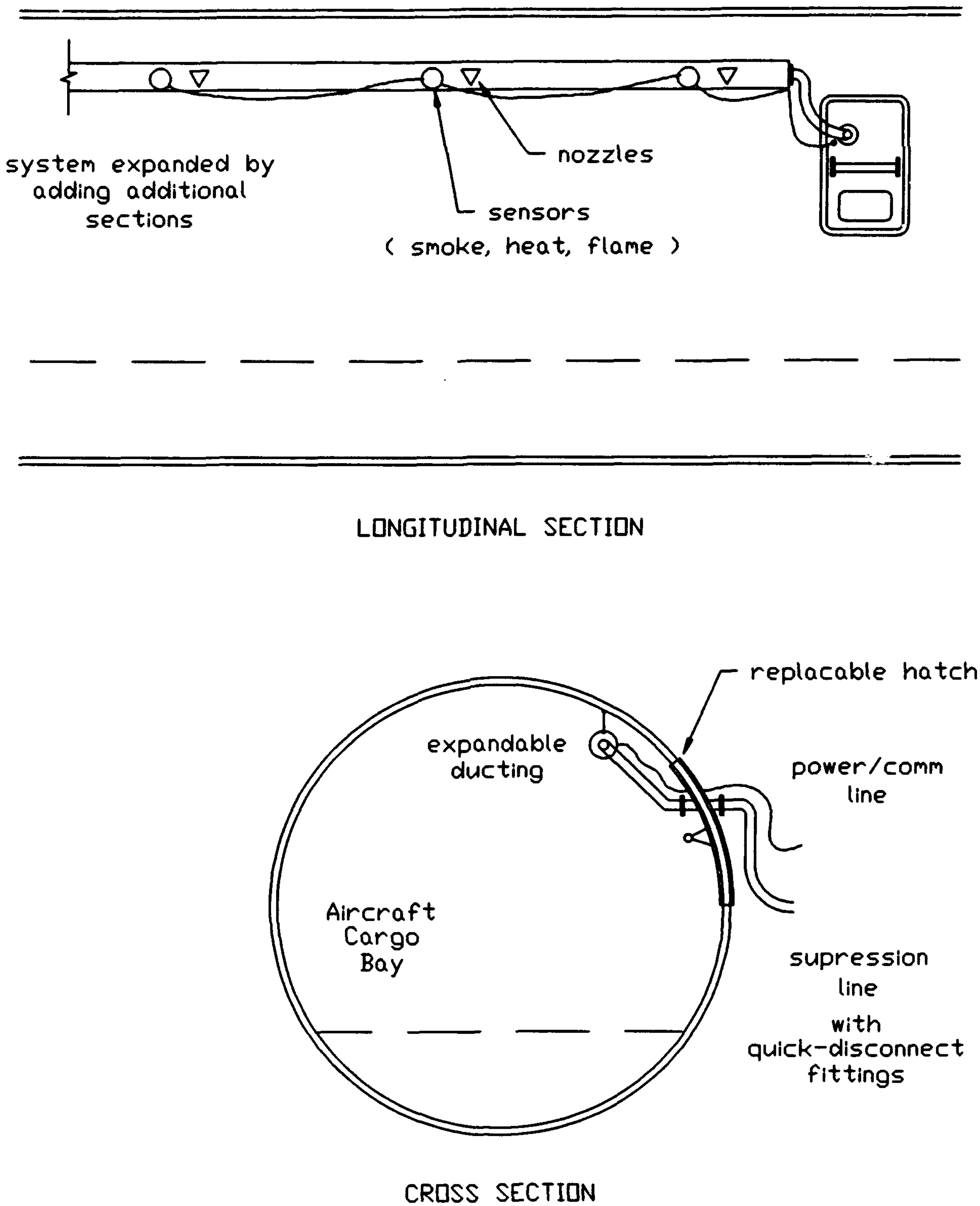


Figure A-9. Combined Dispersion/Detector Design

external cart is shown in Figure A-10. Note that the basic design of the cart is independent of the type of extinguishment agent used, and could be easily retrofitted to accommodate any agent. The body of the cart is used to hold the cylinders containing the extinguishing agent. The cylinders while piped together to act as a single source of agent, are separated into two groups. The first group of cylinders is used to generate the initial concentration levels of agent inside the cargo bay. The second group is used to maintain the concentration levels for the required duration. The two groups of cylinders are connected through an orifice which restricts or controls the flow of agent from the second group of cylinders. During a discharge, all the agent in all the cylinders is released.

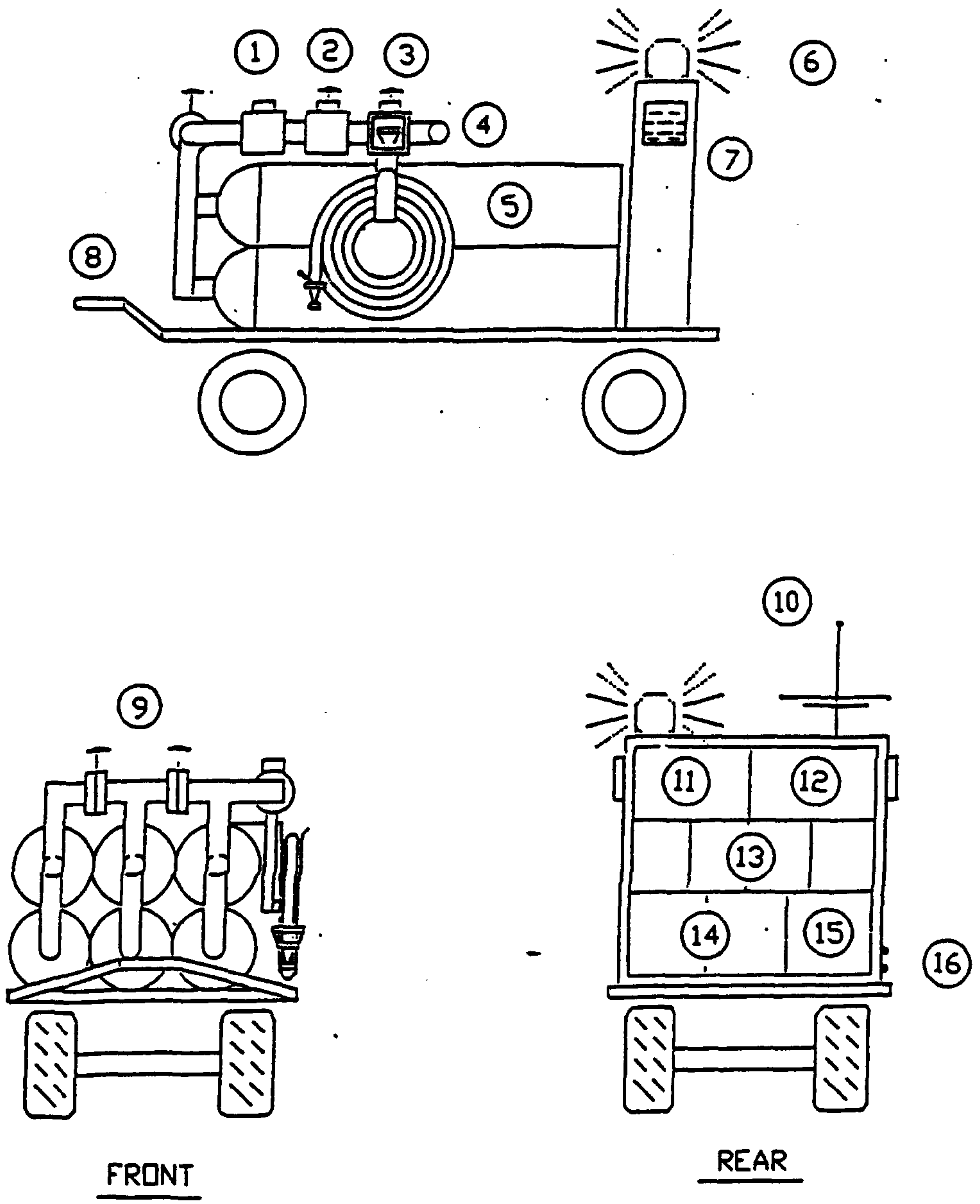
The external cart is also equipped with an additional external hose which provides an additional flight line fire extinguisher capability. A valve is provided on the cart to direct the flow of agent either to the external hose, to the cargo bay or both. If the agent is directed to the cargo bay, all the agent is dispersed during a discharge. If the agent is directed only to the external hose, then another valve at the end of the hose controls the discharging of the agent. All hoses (both the external hose and the hoses supplying the agent to the cargo bay) are equipped with self sealing quick disconnect fittings. These prevent an accidental discharging of agent from an unconnected hose.

The cart is powered by on-board batteries. When the system is not in use, a battery charger is provided to recharge the batteries. The battery charger operates automatically when connected to either aircraft power or a standard wall socket. The cart provides a special location to store the detector modules. The location is designed to automatically recharge the detector modules' batteries and provide additional protection from the elements. The cart is also equipped with a display panel showing the status of the system and printed instructions to show operation of the system to an untrained user. All controls on the cart are clearly marked and positioned for easy operation. Besides the communication link for reporting fires, the cart is also equipped with a portable radio to allow voice communications with the fire station.

The cart is equipped with a standard hitch commonly used on similar type carts and is designed to be towed by a vehicle to the site of the aircraft. Once parked, the emergency door (or equivalent) to the aircraft is removed and set aside. The aircraft fire sentry system's door is then put in its place. The detector modules are removed from the cart and placed in the cargo bay of the aircraft. A hose is then connected from the cart to the replaced aircraft door. The system is now ready to operate.

The system has several different modes of operation. The first mode is a built in test (BIT) which is used to check the operational status of the system. The BIT verifies that each sensor and communication link, and extinguishment system is properly functioning. This helps to verify that the system is installed correctly before one of the monitoring modes is activated.

The system has two monitoring modes of operation. The first mode is used whenever personnel are working in or around the aircraft. In this mode the system provides fire detection only. The automatic extinguishing system is deactivated to



1. AGENT FILL PORT
2. AGENT DISCHARGE VALVE
3. HAND HOSE CONTROL VALVE
4. DISCHARGE HOSE CONNECTOR
5. AGENT CYLINDERS
6. STROBE LIGHT
7. SIREN
8. STANDARD HITCH
9. VARIABLE ORIFICES
10. ANTENNA
11. MASTER CONTROL PANEL
12. TRANSMITTER/RECEIVER PROCESSOR
13. DETECTOR MODULE STORAGE
14. BATTERIES
15. POWER SUPPLY/BATTERY CHARGER
16. AC CONNECTOR

Figure A-10. Preliminary External Cart Design

prevent accidental discharging of the extinguishing agent. In this mode the agent can only be discharged manually from the external cart. If a fire is detected, both visual and audible alarms will sound. An automatic time delay is then initiated before the fire department is contacted to allow the nearby personnel to determine the cause of the alarm and either manually activate the extinguishing agent or reset the system and cancel the alarm. This operating mode is provided to allow nearby personnel the opportunity to first assess the situation and make a determination if contacting fire department or the application of the extinguishing agent is needed. Failure to cancel the alarm within the delay period automatically causes the system to contact the fire department. Discharging of the agent automatically causes the system to contact the fire department. This mode of operation eliminates the possibility of accidentally discharging the agent on nearby personnel, or needlessly contacting the fire department in event of an obvious false alarm.

The second monitoring mode of operation is used to protect the aircraft when no personnel are nearby. In this mode the aircraft is assumed to be in a configuration where false alarm stimuli are not likely to be generated and alarming by the fire detectors has a high probability of indicating the presence of an actual fire. Smart processing of the detector sensor outputs is still performed to minimize any possibility of false alarming. When the system detects a fire, alarms are immediately sounded to warn nearby personnel of the impending discharging of the agent, the fire department is contacted, and the extinguishing agent is automatically discharged. A different alarm signal is used after a discharge to alert responding personnel of the presence of the agent in the cargo bay.

Because of the uncertain future availability and dramatically increasing costs of halon firefighting agents, their use in this system is not recommended. Also due to the limited information concerning the operating characteristics and availability of the only available replacement agent to date, designing the extinguishment system around FM-100 is very risky and beyond the scope of this program. Because this is a developmental program, the design of the system is such that changing agents at a later date is easily accomplished. Due to the environmental and cost impacts, the extinguishing portion of the fire sentry system shall be designed using CO_2 as the extinguishing agent.

5.0. CONCLUSIONS

There is a significant threat of fire on every large frame aircraft. Current fire fighting capabilities are greatly reduced by the limited resources available to report fires from remote sites. As shown by the damage to aircraft caused by fires, the need to provide a means of faster detection and automatic notification of the fire department is critical. National assets such as large frame cargo aircraft which are no longer being manufactured, enhances the need for better protection against fires.

Protection of most aircraft is limited to on board detectors. Only the C5 aircraft has an on board fire extinguishment system. However, these systems are inoperable when aircraft power is off. In the event of a fire, the fire department must rely on a visual confirmation by personnel with a portable radio. This is a very unreliable and slow method for reporting fires. As shown by several independent tests, the intensity of a fire grows very quickly inside a cargo bay. The delay in the fire department ability to respond to a fire is directly proportional to the fire's destructive potential. The fire sentry system being developed under this contract will help minimize the damage caused by a fire by providing early detection, automatic suppression, and immediate contacting of the fire department.

Due to the eventual phasing out of halon fire fighting agents by the year 2000, the type of extinguishing agent that the final fire sentry system which is deployed at actual air bases, should be designed around is still a matter to be determined. The availability of direct drop in replacements for any of the halon agents is very unlikely within the next ten years. The availability of equivalent agents is more likely, but because they are not fully characterized yet the design of a system around one of these agents is very risky. The cost of using halon agents due to their growing demand, dropping production, and very high taxes make them very undesirable for use even in the interim before they are completely phased out.

Because of the built-in flexibility of the proposed system's design, it is not mandatory to use the type of agent which will be used during final system deployment for this initial development phase of the system . Demonstration of the system's effectiveness at protecting cargo bays of large frame aircraft shall be performed using an environmentally safe agent.

A successful demonstration of the system shall show that the system is capable of accurately detecting fires under a number of different cargo bay configurations, and that it is also capable of discharging and maintaining the required concentration levels of the agent necessary to suppress a fire. More importance shall be given to the system's advancement in the area of detection and alarming (notification of the fire department).

Because the detection and the extinguishing portions of the system are being developed independently and the ability of switching over to another extinguishing agent at a later date requires a limited impact to the system's overall design, the use of CO2 is the only reliably available agent and the logical choice for use on this program.

Fire detection devices are designed to be used in areas void of any false alarming stimuli. When false alarm stimuli are present, individual detectors are inherently unreliable. Smart processing logic must be used to minimize the false alarming of individual detectors. To adequately protect the cargo bay of a large frame aircraft the fire sentry system must employ smoke, flame, and heat detectors. The flame detectors are primarily used when the cargo bay is empty. They have extended range and fast response times which are essential for detecting fast moving fires in an empty cargo bay. When the bay is full of cargo, the ability of the flame detectors to "see" is impaired limiting their usefulness in detecting fires only within a small area around the detector modules. When the cargo bay is full, smoke and heat detectors must be used. However, these devices are limited to only measuring the conditions nearby the detector and must wait for the by-products of the fire to reach the detector. As a result, detection using these devices is generally slow allowing a fire to develop before detection is possible.

The fire sentry system must be carefully designed to help ensure its acceptance for use on air bases world wide. Previous studies have shown the effectiveness of various agents to extinguish fires. Considerable data is also available on these agents concerning the designs and hazards of systems based on them. The focus of this program is to develop a fire sentry system which is highly effective at detecting fires and notifying the fire department with a very low probability of false alarming and which people are willing to use.

6.0. RECOMMENDATIONS

It is recommended that the three different types of detector modules and the two different types of extinguishment systems outlined in Section 4.0 be developed for testing on this program. It is also recommended that the developmental extinguishing system be designed to use CO2 as the extinguishing agent for testing purposes. Based on the results of the testing, detailed paper designs for Halon 1301 and 1211 shall be generated. The external cart shall be designed as outlined in Section 4.0.

A study must be performed to determine the availability of controllers for the detector modules and the external cart. This cannot be performed until the exact types of detectors are selected.

Testing of the components shall be initially performed in the laboratory. Testing shall focus on determining the detector module's false alarm immunity and probability of fire detection. Using local field test facilities, the communication portion of the system shall be analyzed to determine its effectiveness at an actual air base and when used in close proximity with several other operating systems.

Finally a packaging study shall be performed to determine the best way to protect the detector modules and the external cart. Additional visitations to air bases may be required to determine the compatibility and operational characteristics of the developed systems to actual aircraft.

REFERENCES

Information used in the preparation of this report was obtained from the following documents.

SPECIFICATIONS

Air Force Engineering Support Agency (AFCESA) Documents:

SETA Contract Number F08635-88-C-0067
Supplemental Support Group Subtask (SSG) 3.14.1

System Operational Requirements - "Aircraft Fire Sentry," SORD 201-84-1

C-5/KC-10/C-130/C-141 - Fire/Explosion
Mishaps on the Ground, 1979 to Date

DESIGN GUIDES

Manufacturers Catalog Publications:

Fire Detection System Selection Guide — Detector Electronics Corp.
6903 W. 110th Street
Minneapolis, MN 55438
(612) 941-5665

Specifying Engineer's Guide to Fire Protection — Ansul Fire Protection
One Stanton Street
Marinette, WI 54143-2542
(715) 735-7411

Walter Kidde Architects and Engineers Manual — Kidde-Fenwal
400 Main Street
Ashland, MA 01721
(508) 881-2000

GOVERNMENT PUBLICATIONS

National Fire Protection Association (NFPA), Batterymarch Park, Quincy, MA 02269:

"Automatic Fire Detectors," NFPA 72E, 1983.

"Carbon Dioxide Extinguishing Systems," NFPA 12, 1989.

"Halon 1211 Fire Extinguishing Systems," NFPA 12B, 1990.

"Halon 1301 Fire Extinguishing Systems," NFPA 12A, 1990.

Presentation material from miscellaneous briefings given by the EPA on reducing ozone depleting materials, imposed taxes, and impacts of the Montreal Protocol and the Clean Air Act of 1990:

"The New CFC (Chloroflourocarbon) Tax," CFC Alliance Special Bulletin, December 1989.

"Title VI -- Stratospheric Ozone Protection," Final Draft of Final Conference Agreement on Stratospheric Ozone and Global Climate Protection, MPB800.

"Final report of the Halons-Technical Options Committee," Technical Progress on Protecting the Ozone Layer, United Nations Environment Program, Montreal Protocol assessment Technology Review, August 11, 1989.

"How Industry is Reducing Dependence on Ozone-Depleting Chemicals," Environmental Protection Agency, June 1988.

"Omnibus Budget Reconciliation Act of 1989," House of Representatives Report 101-386, November 21, 1989.

ARTICLES

Andersen, S. O., et al., "Halons, Stratospheric Ozone and the U.S. Air Force," The Military Engineer, No. 523, August 1989, pp 485-492.

Blake, D. R., and R. G. Hill, "Fire Containment Characteristics of Aircraft Class D Cargo Compartments," FAA Report FAA/DOT/CT-82-156, June 1982.

Calhoun, C. W., and C. Risinger, "Aircraft Fire Sentry," AFESC Report ESL-TR-87-70, July 1988.

Gassmann, J. J., and R. G. Hill, "Fire Extinguishing Methods for New Passenger/Cargo Aircraft," FAA Report FAA-RD-71-68, November 1971.

Gassmann, J. J., "Characteristics of Fire in Large Cargo Aircraft," FAA Report FAA-RD-70-42, September 1970.

Grant, C. C., "Halons and the Ozone Layer: An Overview," Fire Journal, September/October 1989, pp 59-81.

Grant, C. C., "Halon Design Calculations," Fire Protection Engineering, National Fire Protection Association, 1988, Section 3 59-80.

Hemond, R., and R. Wendt, "The Technology of Infrared and Ultraviolet Detectors," Reprint from Fire Journal, July 1982.

Huston, P. O., "Halon Conservation Efforts in Fire Protection Industry," Firewatch, Volume 27, No. 1, 1990, pp 24-26.

Moore, D. W., "Halogenated Agents and Systems," Fire Protection Handbook, 16th ed., Quincy: National Fire Protection Association, 1986, Section 19, pp 2-10.

Robaidek, M. F., "Aircraft Dry Bay Fire Protection," Air Force Weapons Lab Report AFWAL-TR-87-3032, July 1987.

Schifiliti, R. P., "Design of Detection Systems," Fire Protection Engineering, National Fire Protection Association, 1988, Section 3, pp 1-20.

Schulman, M. R., and T. F. Sawyer, "Fire Department Emergency Communication Systems," Fire Protection Handbook, 16th ed., Quincy: National Fire Protection Association, 1986, Section 16, pp 2-11.

Williamson, H. V., "Carbon Dioxide and Application Systems," Fire Protection Handbook, 16th ed., Quincy: National Fire Protection Association, 1986, Section 19, pp 2-10.

Zimmerman, C. E., "Automatic Fire Detectors," Fire Protection Handbook, 16th ed., Quincy: National Fire Protection Association, 1986, Section 16, pp 29-39.

(The reverse of this page is blank.)

APPENDIX B

SYSTEM DESIGN AND COMPONENT TESTING

(The reverse of this page is blank.)

AIRCRAFT FIRE SENTRY

SYSTEM DESIGN AND
COMPONENT TESTING

Task 2 Report
CDRL DI-A-7088

Prepared for:

Prepared for Headquarters, Air Force Engineering Services Center,
Scientific and Engineering Technical Assistance (SETA)
Tyndall Air Force Base, Florida 32403

Contract Number F08635-88-C-0067
Supplemental Support Group Subtask (SSG) 3.14.1

Prepared by:

Applied Research Associates, Inc.
7114 W. Jefferson Avenue, Suite 305
Lakewood, Colorado 80235

Peter T. Dzwilewski
Principal Investigator

Written by:

Robert Mugele

Date: 29 January 1992

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

Figure Page

1.0 SCOPE

The scope of this report will cover in detail Task 2, "Aircraft Fire Sentry Design and Component Testing." It will include descriptions of the tests and the instrumentation used to gather data and evaluate performance. Test results will be presented and observations noted. Cost of the "Small-Scale" Task 2 system will be discussed. Finally, recommendations for the final prototype will be described.

2.0 SMALL SCALE "BREADBOARD" DESIGN DESCRIPTION

The Aircraft Fire Sentry (AFS) System concept described under Task 2 is comprised of a remotely located, self-contained unit which detects fires and notifies a central unit via radio frequency link. The heart of the AFS is the remote Transmitter/Receiver (Tx/Rx) which would be the unit placed inside parked cargo aircraft.

The remote Tx/Rx is a Monaco Enterprises BT2-3 Building Transceiver. The BT2-3 has been modified to include a photoelectric smoke detector with an integrated heat sensor and a horn. Further modifications include a strobe and manual hand pull station on the exterior of the unit. The stand-alone remote Tx/Rx is powered by four internal 12V/1.2AH rechargeable batteries, connected in parallel which should give the unit an operational duration of a minimum of 60 continuous hours without a recharge. The remote Tx/Rx is portable and easy to install. Overall dimensions are 7 in. x 11 in. x 14 in. and weight is 20 lbs. The normal system antennae are the BSA-1 VHF Omnidirectional Antenna Assembly which are located at both the BT2-3 and the central Tx/Rx units. This system transmits at a frequency of 138.925 Mhz.

The photoelectric smoke detector, Centex Model 8120PT, has a nominal sensitivity of 2.5% per foot obscuration. The thermal sensor was selected with an initial level of 135°F and the piezo horn had an audio level of 90 dB.

Smoke, heat, and manual pull inputs are connected to zone addresses inside the BT2-3. The zones are uniquely addressable input locations inside the BT2-3 that can give specific information about the nature of the alarm. Scanning of zones occurs at the rate of about twice per second. There are five zones available, two of which are used. One is used for smoke/heat, and the other is used for manual pull.

The central Tx/Rx is a Monaco Enterprises D-500 plus Advanced Wireless Information Management Alarm Receiving and Reporting System. The unit is AC or DC powered, and is computer based. Its unique software is specifically developed for managing conditions of remote units like the BT2-3. Similar to the remote unit, it also has transmitting and receiving modules to allow it to communicate to remote units. Once every hour the central Tx/Rx interrogates the remote's status. Their reply indicates AC/battery power, tamper, or system trouble and alarm conditions, if any. During operation of the entire system, an alarm message would be received, a message displayed on the computer screen, and an audible tone heard approximately 6 seconds after the remote unit has detected a fire and sent an alarm message.

When the BT2-3 is powered up, it monitors the battery power and alarm/trouble indications at the various zone locations. If a detector if activated, or if the manual handle is pulled, an alarm signal will be sent to the corresponding zone address and the BT2-3 will transmit an alarm message to the central Tx/Rx by the RF link. The central Tx/Rx would normally be located at the base fire department. The information received at the fire department would tell which zone triggered the alarm and thus where the fire is located.

3.0 TEST DESCRIPTIONS

The performance of the AFS system was demonstrated through a series of various functional tests. The tests were designed to allow an objective evaluation and to determine if the system meets the requirements as set forth in the Statement of Work.

The test series is composed of four types of tests: 1) 60-Hour Operational Test, 2) Manual Pull Station Test, 3) Heat Test, and 4) Live Test. Each type of test was repeated to show system repeatability. The live testing can be further divided into smoke and fire tests.

The 60 Hour, Manual Pull and Heat tests were conducted at the Applied Research Associates Lakewood, Colorado laboratory. The live tests were carried out at ARA's remote test site which is approximately 30 miles east of Denver, Colorado. These tests were conducted at this location for two reasons. First, it allowed for a significant distance between the test location and the location of local owners of the same radio frequency (138.925 Mhz). To further minimize interference, all tests were run using a 50-ohm dummy load as the antenna in an effort to reduce radiated signal strength. The second reason relates to safety. The potentially dangerous nature of fire testing cannot be done at the scale required in laboratory conditions. ARA's outdoor test site is suited for hazardous testing. Figures B-1 and B-2 show the location of the test site.

A structure in which the tests were conducted was constructed at the test site, with a geometry resembling the cross-sectional shape of a C-130 aircraft. The length, however, is approximately one-third (16 ft) that of the aircraft. Figures B-3, B-4, and B-5 show this structure.

The test plan is found in Annex A.

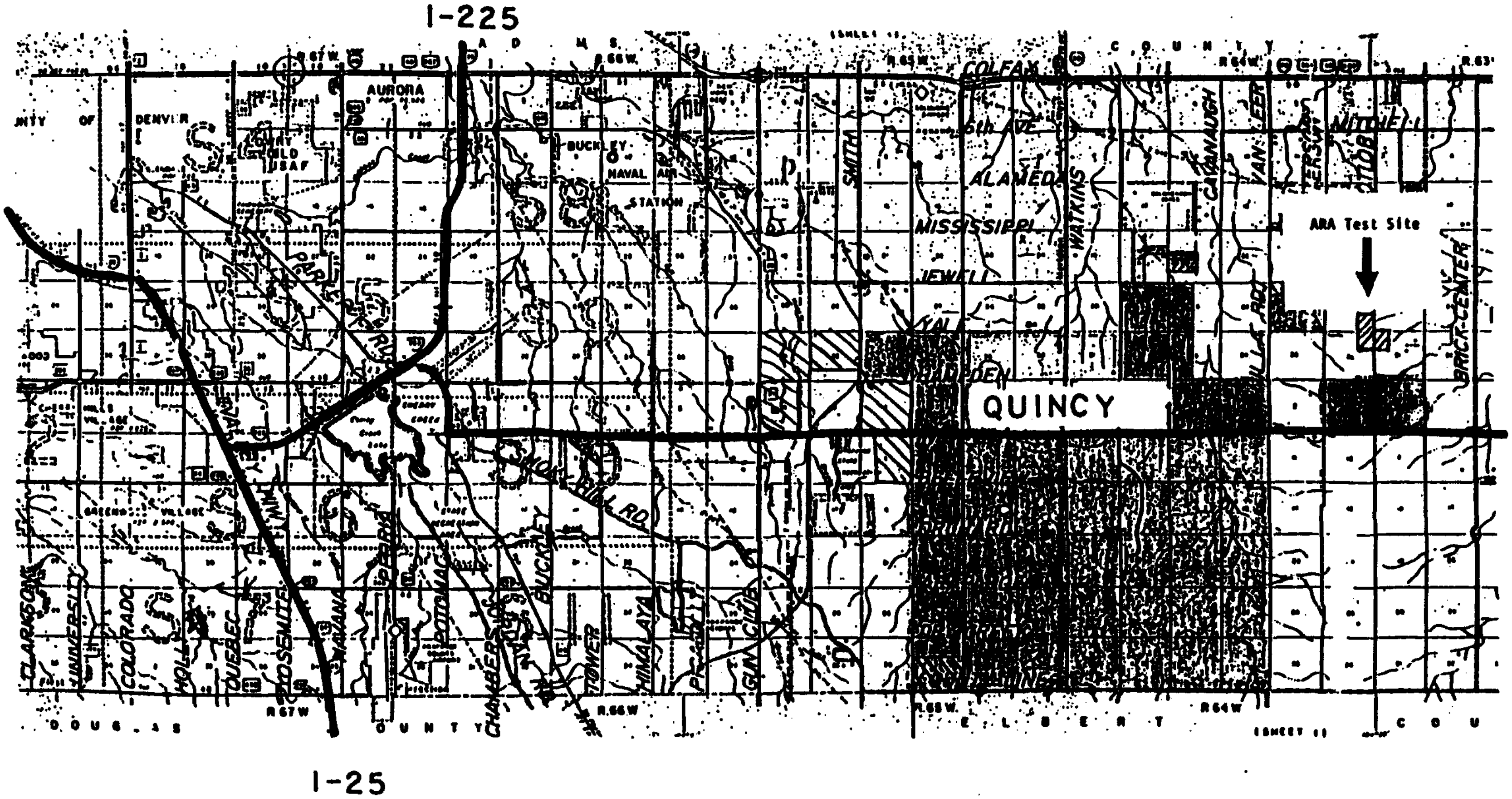


Figure B-1. Test Site Location

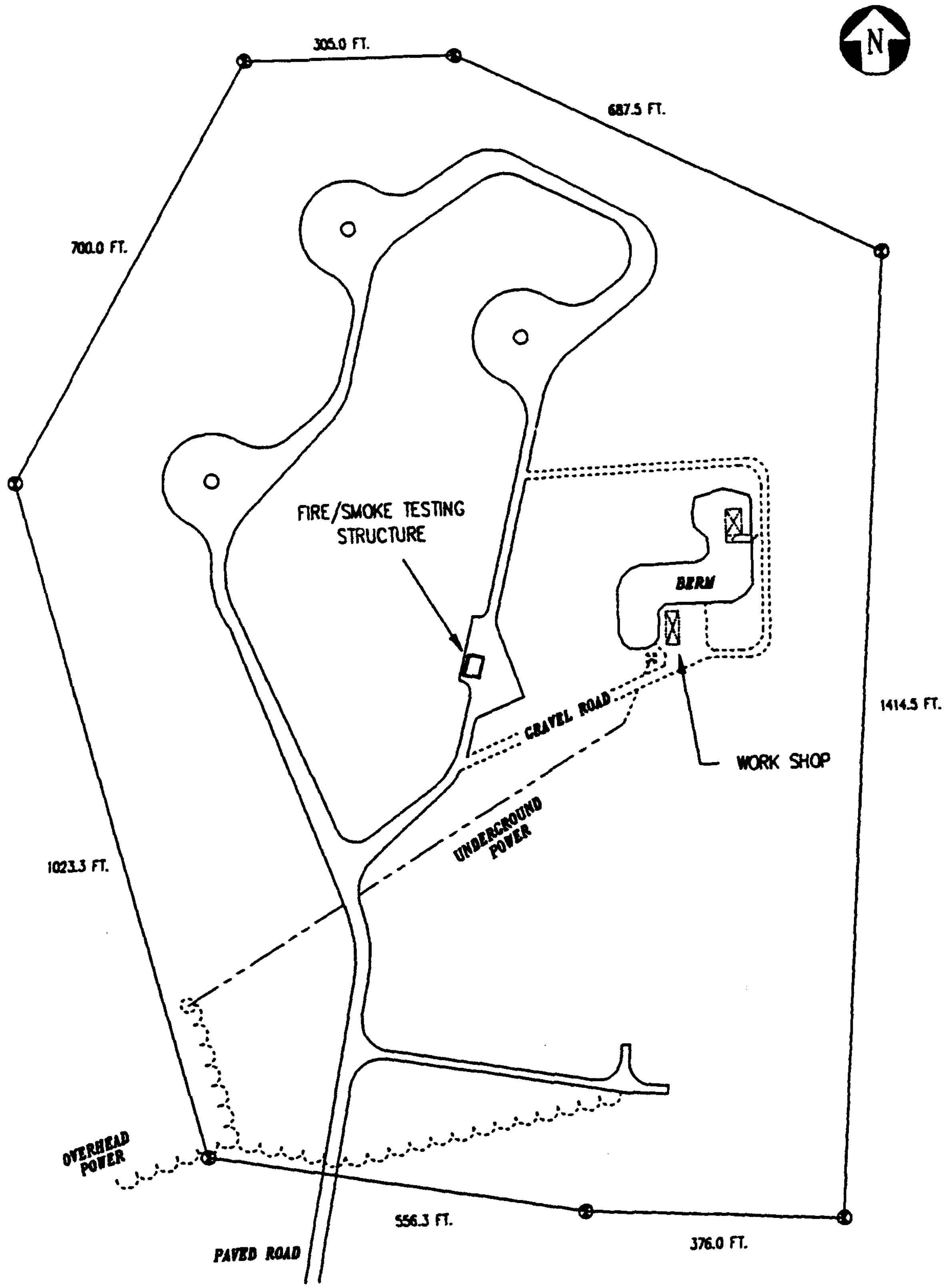


Figure B-2. Test Site Detail

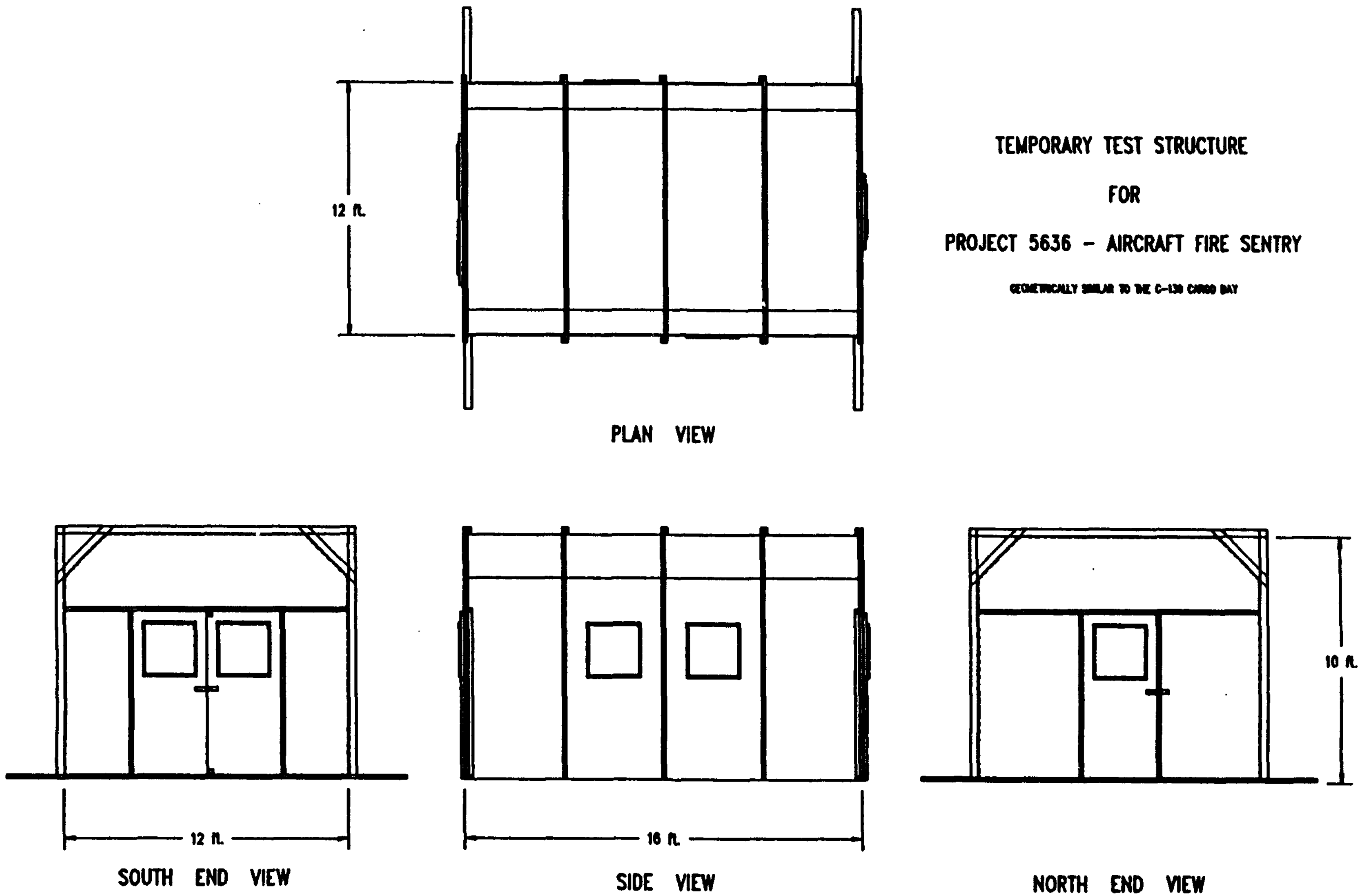


Figure B-3. Dimensions of Test Structure

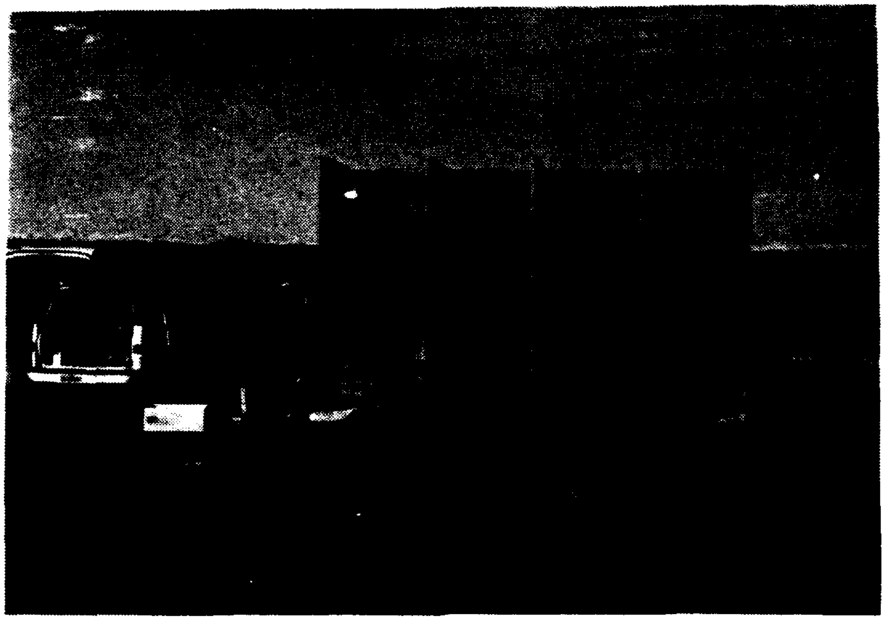


Figure B-4. Side View of Structure with Instrumentation Van

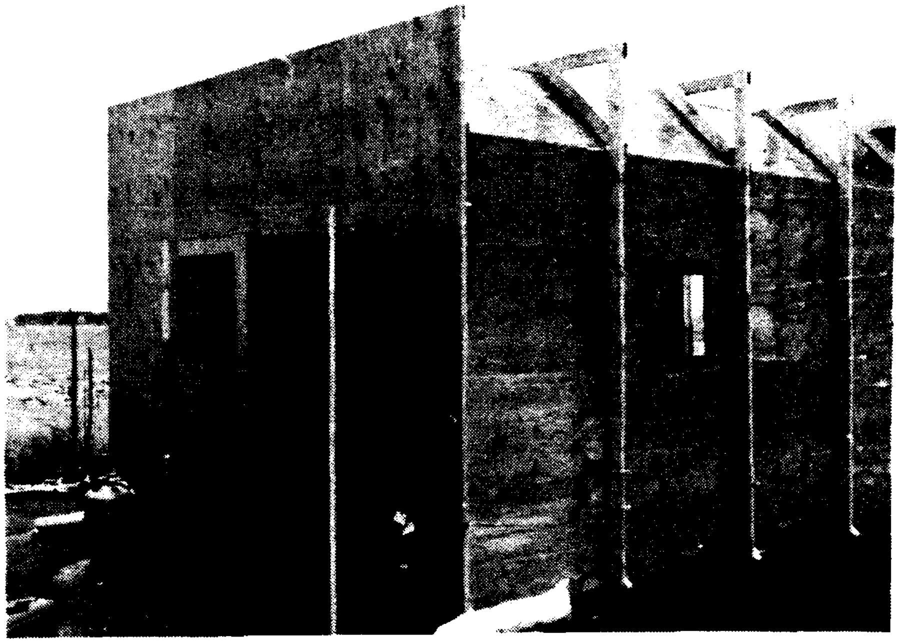


Figure B-5. Live Smoke/Fire Test Structure

4.0 INSTRUMENTATION

The performance of the remote Tx/Rx and the central Tx/Rx were the focus of any individual test. The remote unit is subjected to some kind of stimulus and then transmits a message to the central unit. In each case, this requires operation of the RF link. To independently verify the test environment, various instruments were used to capture the data.

The instrumentation used included:

smoke density/obscuration detectors,
thermocouples,
duration trigger box,
stopwatch,
digital recorders,
video,
black and white still photography,
IR photography,
voltmeters,
portable radio scanner.

For the Smoke and Live Fire tests, smoke density was measured and converted into percent obscuration per foot. This is the standard to indicate sensitivity of commercial smoke detectors (reference: UL 268 "Smoke Detectors for Fire Protective Signaling Systems"). The main components of a smoke obscuration detector are a lamp with a power supply and a photocell with signal conditioning. These components are mounted to a structure which separates the lamp and photocell by exactly five feet. During operation, with the lamp on, an amperage is created in the photocell and converted to an analog voltage output by the signal conditioner (Figures B-6 through B-9 show the device used).

As smoke passes between the lamp and photocell, the amperage created by the photocell decreases. At any distance, the percent obscuration per foot can be calculated by:

$$S.O. = \left[1 - \left(\frac{V_F}{V_I}\right)^{\frac{1}{D}}\right] 100$$

where: S.O. is percent obscuration per foot,
V_F is voltage reading with smoke,
V_I is voltage reading in clean air,
D is distance between lamp and photocell.

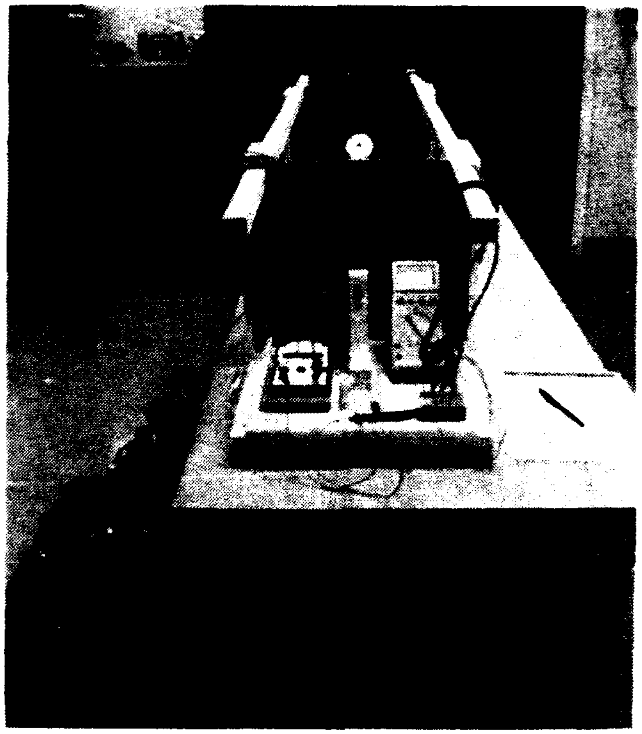


Figure B-6. Smoke Obscuration Detector

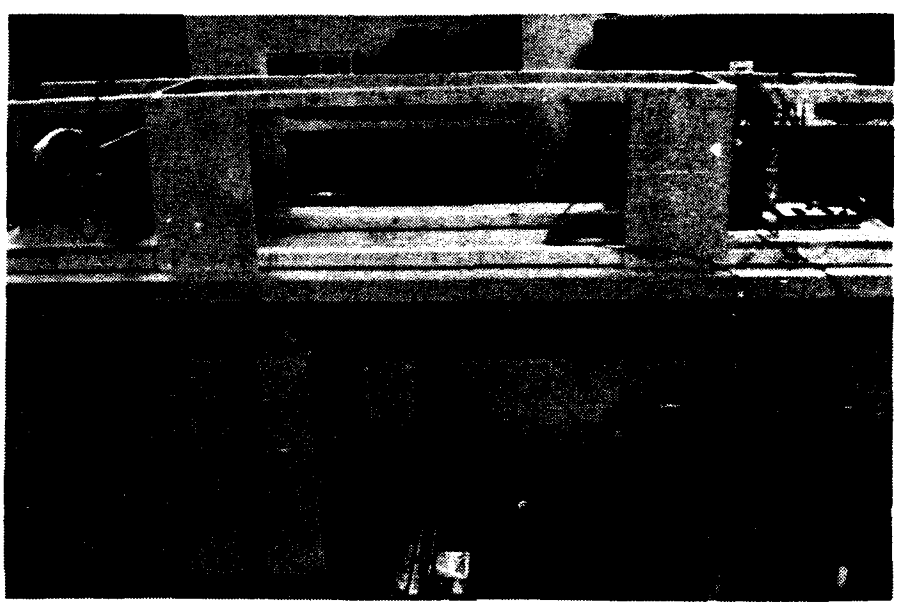


Figure B-7. Detector - Side View

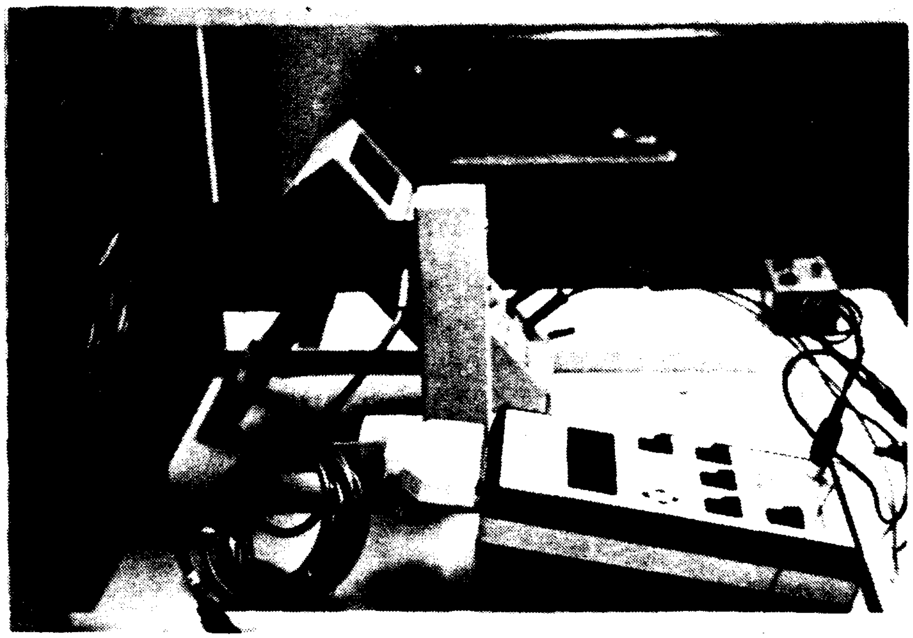


Figure B-8. Detector - Photocell and Radiometer

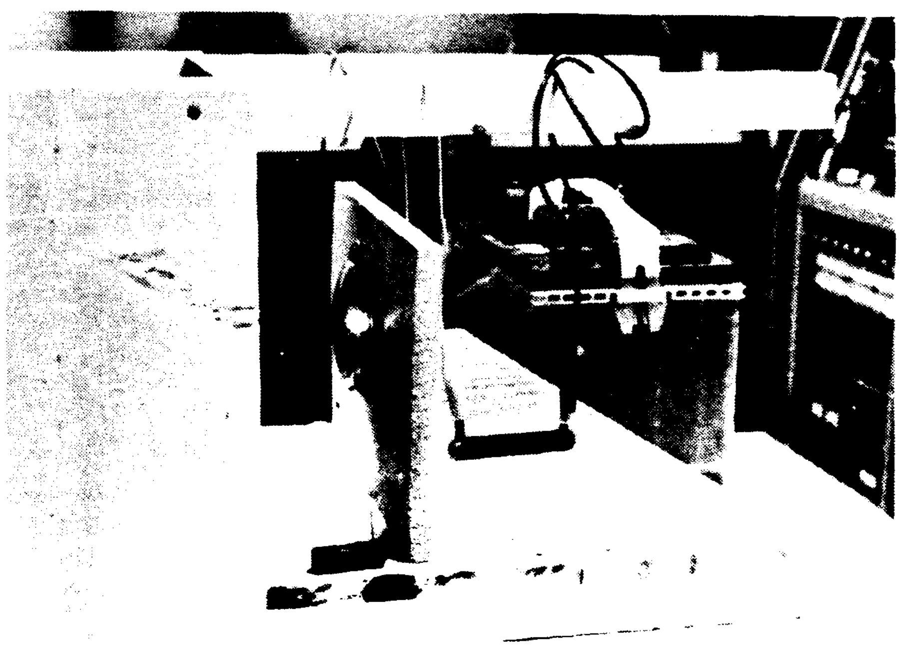


Figure B-9. Detector - Lamp and Power Supply

Fast response thermocouples were used to monitor temperature during the Heat and Live Fire tests. The current generated by the thermocouple was conditioned by a digital pyrometer. The pyrometer used the thermocouple output, referenced it to 32°F, linearized and amplified the signal, then output a 0 to 5 volt DC signal. The pyrometer also has a 4 digit display to observe the temperature in real time.

Time reference for the Smoke and Live Fire tests was generated by a hand-held, 9 volt trigger box. As the smoke began or the fire set, the box was manually activated. This created a time reference for the recorders and also initiated recording of smoke obscuration and temperature signals. When the alarm was generated by the AFS unit, the trigger was deactivated, which sent another time reference signal to the recorders. A hand-held stopwatch was used as a back-up and during manual and heat testing.

Recording of data during the Smoke and Live Fire tests was achieved by stand-alone Digistar II digital recorders. Manually monitoring voltmeters and the digital pyrometers, and documenting values at critical times was also performed.

Photodocumentation of the tests was accomplished with a color VHS video camera, a 35 mm SLR camera with black and white film, and 35 mm photography using infrared film and filters, during the Live Fire tests. The tripod-mounted infra-red photography was focused in the direction of the BT2-3 unit during these tests.

As a backup, a portable radio scanner preset to 138.925 Mhz was used to pick up alarm signals in the event the central Tx/Rx did not.

5.0 TEST RESULTS

A total of 25 separate functional performance tests on the AFS system were successfully conducted during November 1991. Three 60-Hour Operational, two Manual Alarm, five Heat and fifteen Live Fire/Smoke tests were conducted. Of the last fifteen tests, eleven tests used a commercial smoke generator as a smoke source and four were live fires. The AFS system passed all tests as described in the Task 2 - Prototype System Test Plan. The detailed results of the tests are described below. The completed test records used from the test plan are in Annex B.

For all tests, the BT2-3 was fully charged and powered by its internal batteries. The antenna systems used were 50 ohm dummy loads. The distance between the remote and central units was never more than 30 feet.

Some intermittent operation of the central Tx/Rx was experienced during a few of the tests. The central unit on occasion would not accept BT2-3 signals. Most of the problems were traced to the receiving module in the central Tx/Rx. No test was conducted until the RF link was established. This usually involved using the central Tx/Rx to interrogate the BT2-3 for its status. When the BT2-3 unit responded promptly with the correct message, the test was conducted.

The portable DC power supply for the central Tx/Rx was never used, as it never fully charged to 12 volts and would not transmit on cool days at the test site. It is believed that the rechargeable battery in the power supply might have outlived its usefulness. The central Tx/Rx (D-500 Plus) and its power supply were on loan to this project from Tyndall AFB.

5.1 60-Hour Operational Tests

Three 60-Hour Tests were conducted to fulfill the requirement that the BT2-3 could still transmit alarm messages after operating for 60 hours under its own internal battery power.

The first test was carried out under normal indoor ambient conditions of 72°F, and low humidity. Transmission was successful after 60 hours. Battery voltage measured 11.58 VDC at this time, and the "low batt" LED was on. The test was continued, and the last good transmission was made at 68 hours.

The second test was carried out under the same environmental conditions as the first test. Its objective was to corroborate the results of the first test. The transmission was successfully completed at 60 hours. Battery voltage was measured to be 11.45 VDC.

During the third 60-Hour Test, the BT2-3 was placed in refrigerated conditions which averaged 33°F for the entire test period. The unit responded to central Tx/Rx interrogations through the 60 hour period and ultimately ran for

73.5 hours. Battery voltage as this point measured 7.79 VDC. The "low batt" LED appeared at the 45-hour mark.

5.2 Manual Alarm Tests

The objective of the manual alarm tests was to verify performance of the manual alarm handle modification on the BT2-3.

Two separate tests were conducted, each with multiple pulls of the manual alarm handle. Each time the handle was pulled, an alarm message was received at the central Tx/Rx. When the handle was returned to its normal position, an "all normal" message was received at the central Tx/Rx. The average elapsed time between activation and alarm message at the central Tx/Rx was 6 seconds.

5.3 Heat Tests

The objective of the heat tests was to test the BT2-3 heat sensor's ability to detect an overheating condition in its vicinity and send an alarm message to the central Tx/Rx. The heat sensor was rated at 135°F and an integral part of a commercial smoke/heat detector. For all heat tests, a fast response thermocouple with digital readout was used to independently monitor the temperature. The thermocouple was attached to the front face of the heat sensor. Pictures of the test setup are found in Annex D.

The first heat test used a cigarette lighter to slowly apply heat to the sensor until alarm. After 69 seconds, the temperature increased from 73°F to 166°F. The strobe and audible horn activated, and the alarm message was received at the central Tx/Rx.

The second test again used a cigarette lighter as the heat source. Temperature increase was from 69°F to 120°F over a period of 53 seconds. The correct alarm message was received at the central Tx/Rx.

For the third heat test, the sensor was subjected to a different type of heat source - a portable radiant electric heater. During the checkout of the heater to see if it could raise the temperature to acceptable levels, the plastic case of the smoke/heat detector started to melt and slightly deformed. This occurred as the temperature was being increased to about 120°F over a period of 90 seconds. The detector was verified still fully operational by triggering both the heat and smoke detectors, and monitoring the central Tx/Rx for the correct message. A heat shield was then fabricated from 1/8-inch cardboard covered with aluminum foil to protect the smoke/heat detector casing from any additional damage during testing. During the further tests, the temperature was increased from 71°F to 200°F over a period of 139 seconds before the unit alarmed.

The fourth used the portable heater, but two thermocouples were installed to monitor temperature at the sensor - one on the front face and the other on

the back face. Temperatures increased from 81°F to 200°F (front) and 209°F (back) over 106 seconds. At this time, the unit went into alarm, and the message was received at the central Tx/Rx.

The final heat test used the heater to apply a constant 135°F temperature over a long period of time to see if the sensor would trigger at its 135°F rating. Temperature ranged between 135°F and 145°F for 5 minutes without the unit going into alarm. Another minute elapsed as the temperature was increased to 165°F before an alarm message was sent. During this test, the plastic base plate for the strobe deformed. It was not protected with a heat shield similar to the smoke/heat detector. However, the strobe remained operational.

A performance characteristic was noted that the strobe and horn would not deactivate until the heat sensor had cooled off or the entire BT2-3 was powered down.

5.4 Smoke/Live Fire Tests

The final tests were the smoke/live fire tests. These tests were conducted inside a test structure described in Section 3.0. Multiple tests were run, changing the height of the BT2-3 to determine where the BT2-3 is most effective. The four heights were at floor level, three feet, six feet, and ceiling level. The smoke/fire source was always in the same location, on the floor against the wall opposite the BT2-3. Additional instrumentation used to measure the environment were smoke obscuration detectors, thermocouples, a timing system, video and IR photography as described in Section 4.0 Layout of the equipment in the structure and their relative placement to each other for each test is shown in Figure B-10.

The tests were divided into two categories - smoke and live fire. Eleven smoke tests using smoke generators were conducted prior to the live fire tests to exercise the AFS and to evaluate the test equipment. For these tests, one smoke obscuration detector system was placed near the smoke source in an effort to quantify the smoke source. The other obscuration detector was positioned 10 inches from the BT2-3 to quantify smoke density during the course of a test. These measurements were digitally recorded during the test. The obscuration measurements near the source provided interesting data, but this data was not used to gauge the BT2-3 performance. No useful data was gathered by this detector during the live fire tests, as the photocell would overrange when exposed to flames at this close proximity. The temperature measuring system and IR photography were not used due to lack of a heat source.

The commercially produced smoke generators were used as smoke sources for all the smoke tests. These generators are advertised to produce 4000 cu. ft. of grey-white smoke which is 10 times denser than smoke from burning crude oil, over a period of 30 seconds. There was no soot or residue on any test apparatus after a test. As it turns out, based on analysis of the test results which will be discussed later, it was concluded that the smoke generators did not provide a valid source and hence

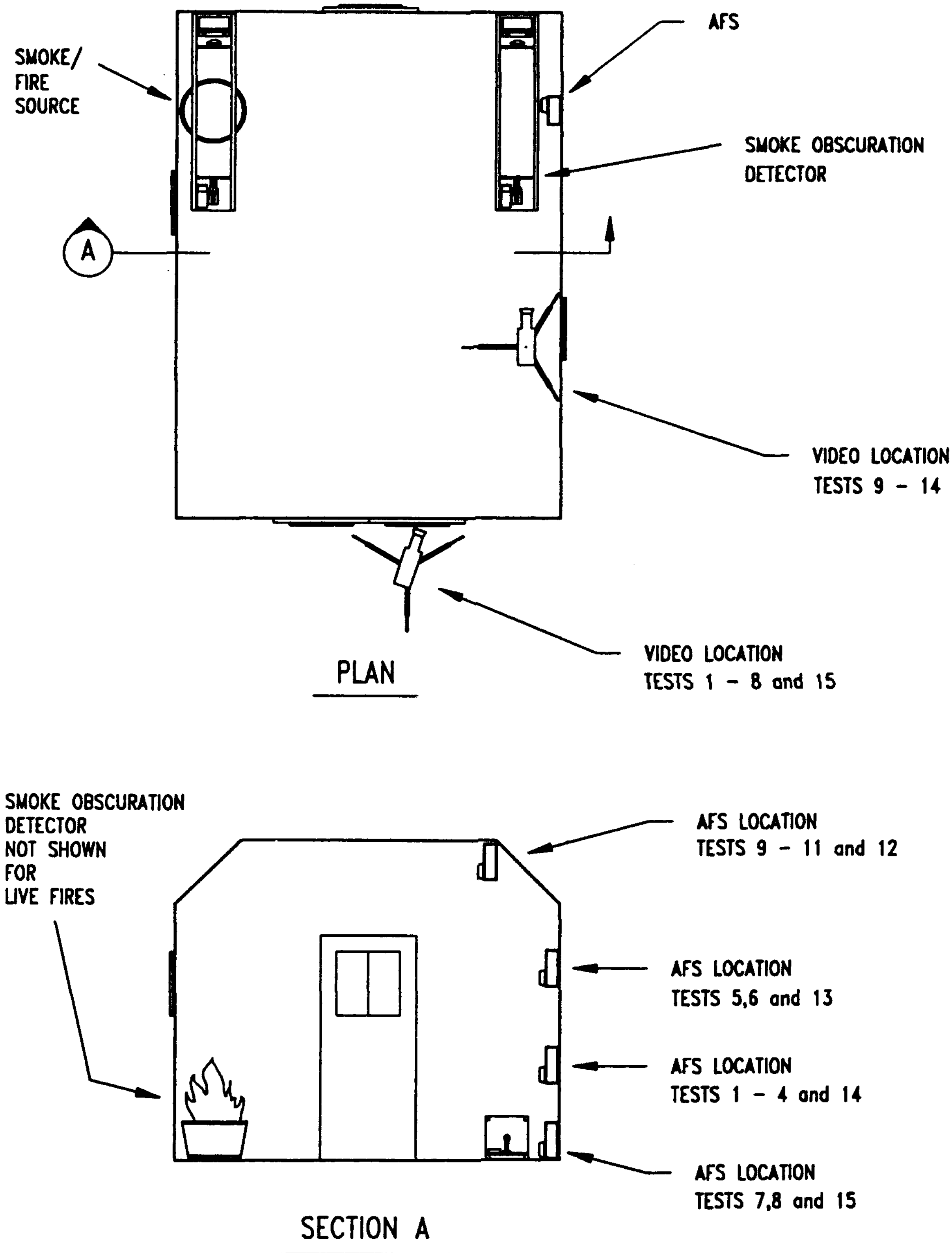


Figure B-10. Equipment Layout in Structure

the results could not be generalized to real fires. These smoke tests are still of value to evaluate the functionality and repeatability of the system components.

Test 1 (Smoke Test 1): BT2-3 was placed at 3 feet above floor level. Ambient temperature was 45°F. This test was essentially conducted as a dry run to debug all hardware and software. Time to alarm was 81 seconds after smoke generation began. Hand-recorded values indicate 10.3% obscuration per foot at the BT2-3 at the time of alarm. No digital/graphical records were obtained at the time of alarm because the recorders were programmed with a too-short duration. The recorders' sampling time were extended for subsequent tests. The AFS did operate properly, and the correct alarm message was received at the central Tx/Rx.

Test 2 (Smoke Test 2): BT2-3 was placed at 3 feet above floor level. Ambient temperature was 45°F. Time to alarm was 89 seconds. Again, the recorders did not capture all of the data. Software changes were made to increase the sampling rate to 10 times original value. Hand-recorded values indicate 3.7% per foot smoke obscuration at the BT2-3 at the time of alarm. AFS operated properly via RF link.

Test 3 (Smoke Test 3): BT2-3 was placed at 3 feet above floor level. Ambient temperature was 61°F. Time to alarm was 119 seconds. Smoke obscuration at the BT2-3 at the time of alarm was measured at 4.6% per foot (see Figure B-11). The RF link worked correctly.

Test 4 (Smoke Test 4): BT2-3 was placed at 3 feet above floor level. Ambient temperature was 66°F. Time to alarm was 124 seconds. Obscuration levels measured at the BT2-3 at the time of alarm were 6.5% per foot (see Figure B-12) and the correct alarm message was received.

Test 5 (Smoke Test 5): BT2-3 was placed at 6 feet above floor level. Ambient temperature was 65°F. Time to alarm was 121 seconds. Obscuration near the BT2-3 measured 8.7% per foot at the time of alarm (see Figure B-13). The correct message was received at the central Tx/Rx.

Test 6 (Smoke Test 6): BT2-3 was placed at 6 feet above floor level. Ambient temperature was 68°F. The alarm went off at 170 seconds. Smoke obscuration was measured to be 7.9% per foot at the time of alarm (see Figure B-14). A maximum obscuration of 17.7% was reached 76 seconds prior to alarm before dropping off. The smoke detector on the BT2-3 took 50 seconds longer to react than the previous test at the same height. The correct alarm message was received at the central Tx/Rx.

Test 7 (Smoke Test 7): BT2-3 was placed on the floor. Ambient temperature was 67°F. Time to alarm was 177 seconds. Smoke obscuration at the BT2-3 was measured at 0.7% per foot at the time of alarm (see Figure B-15). The correct alarm message was received at the central Tx/Rx via RF link.

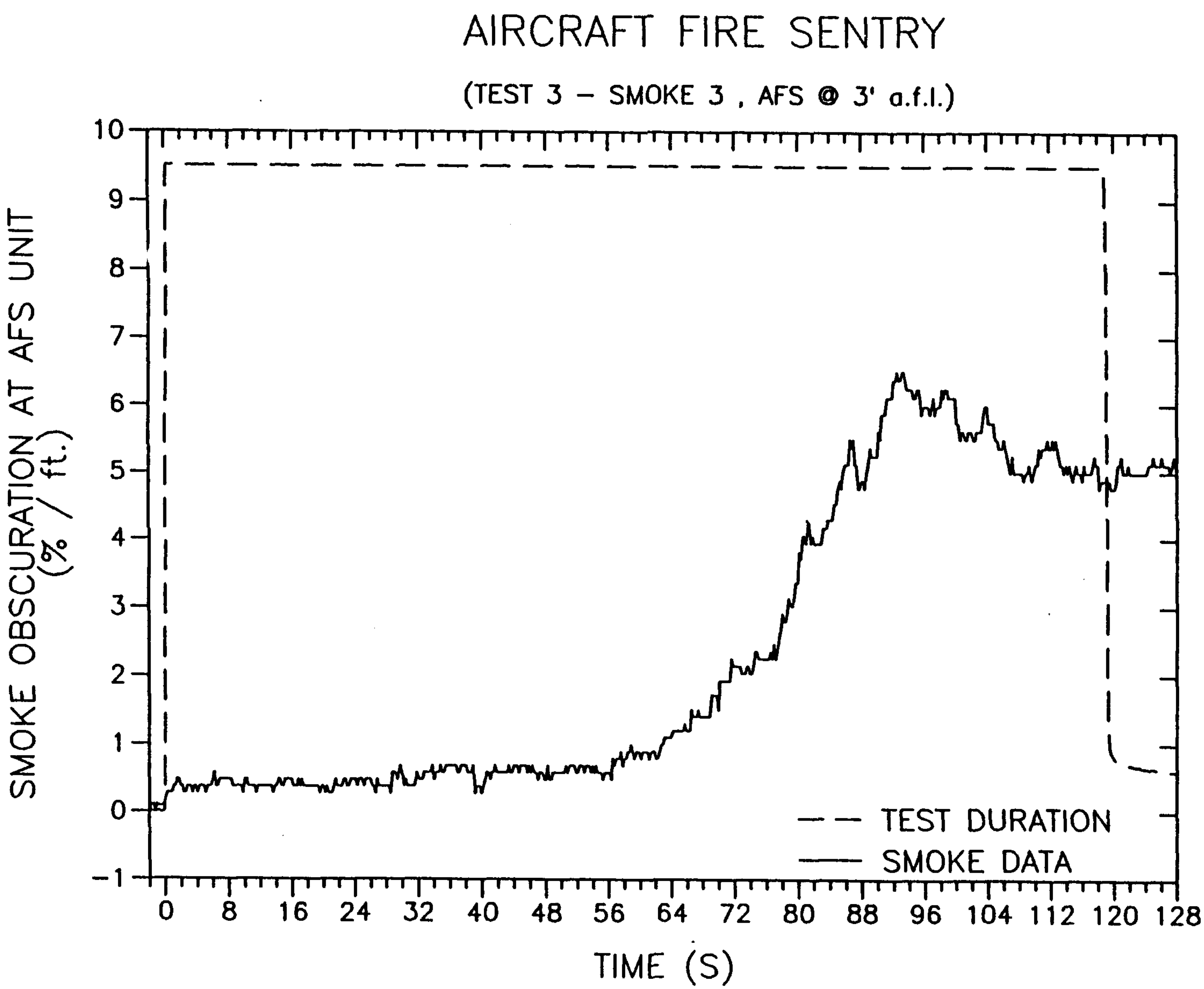


Figure B-11. Smoke Obscuration Near AFS vs. Time - Test 3

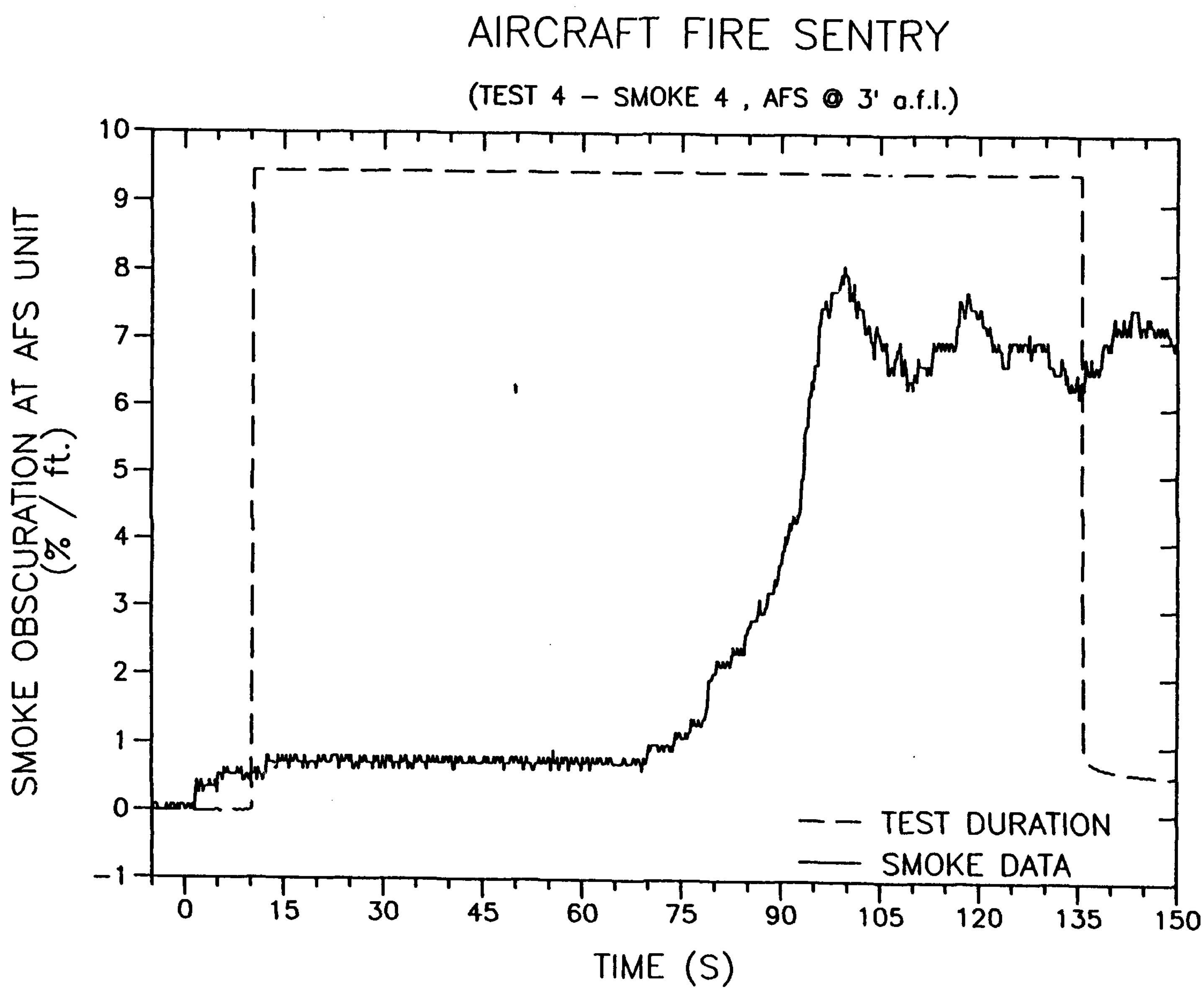


Figure B-12. Smoke Obscuration Near AFS vs.Time - Test 4

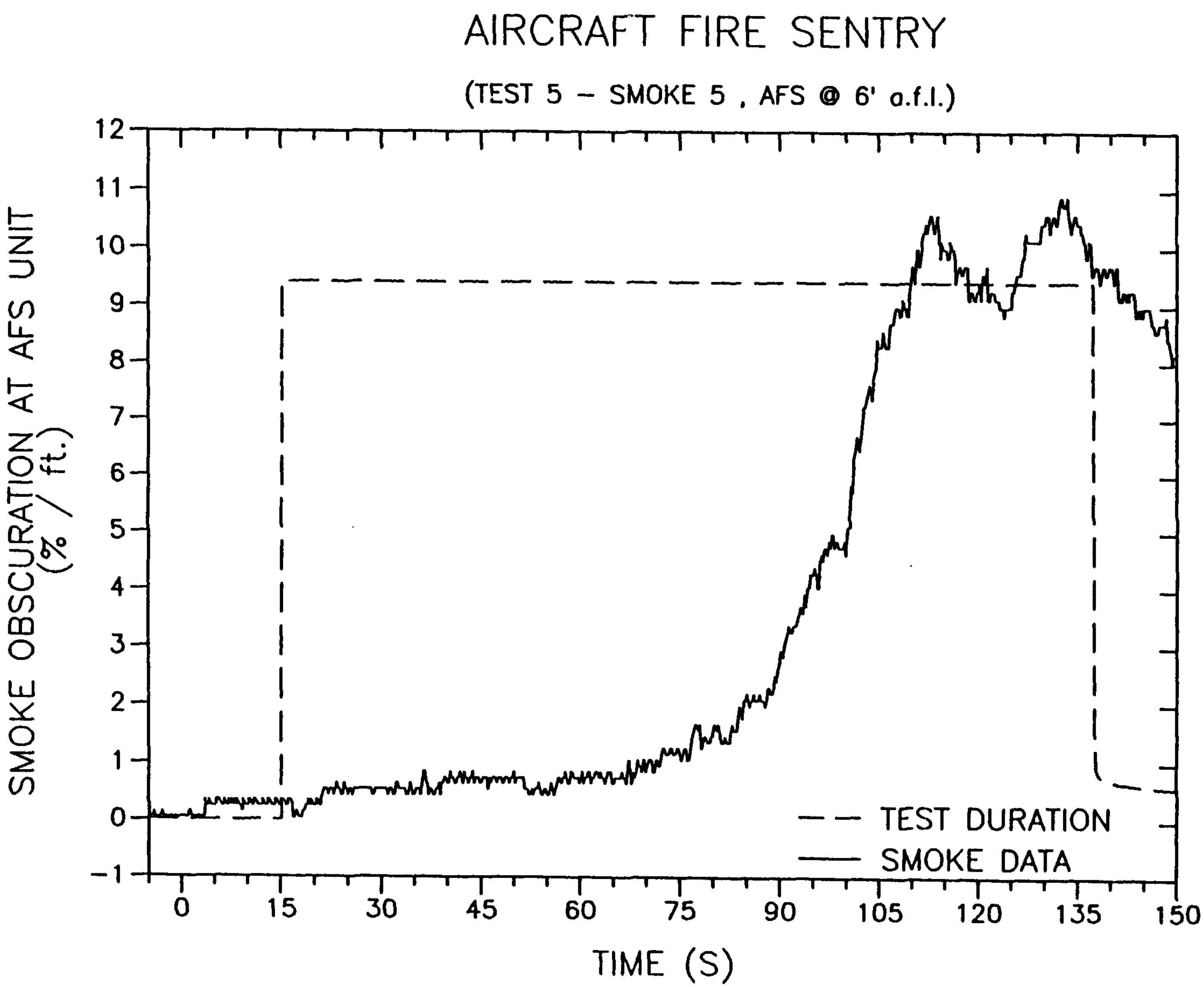


Figure B-13. Smoke Obscuration Near AFS vs. Time - Test 5

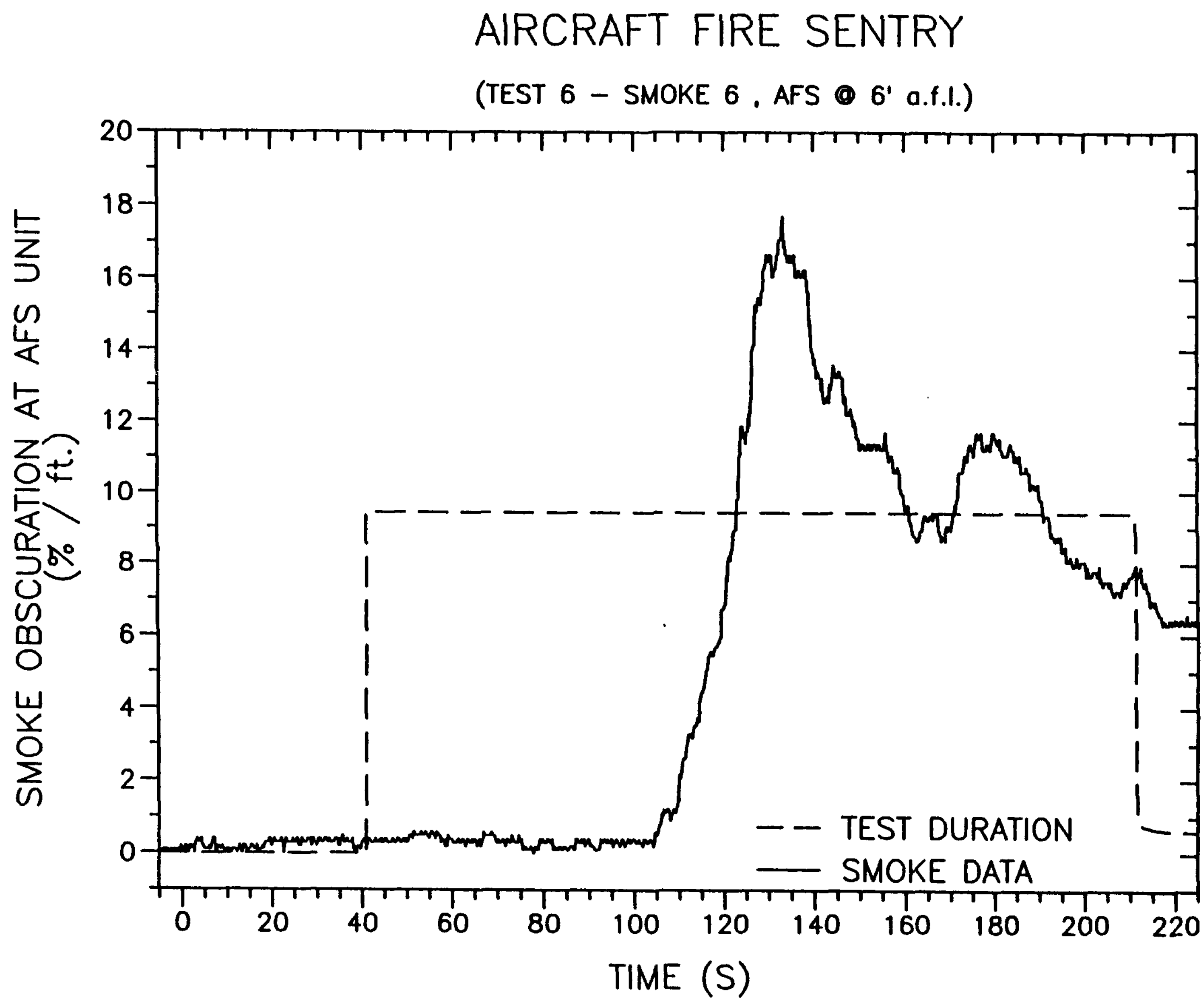


Figure B-14. Smoke Obscuration Near AFS vs. Time - Test 6

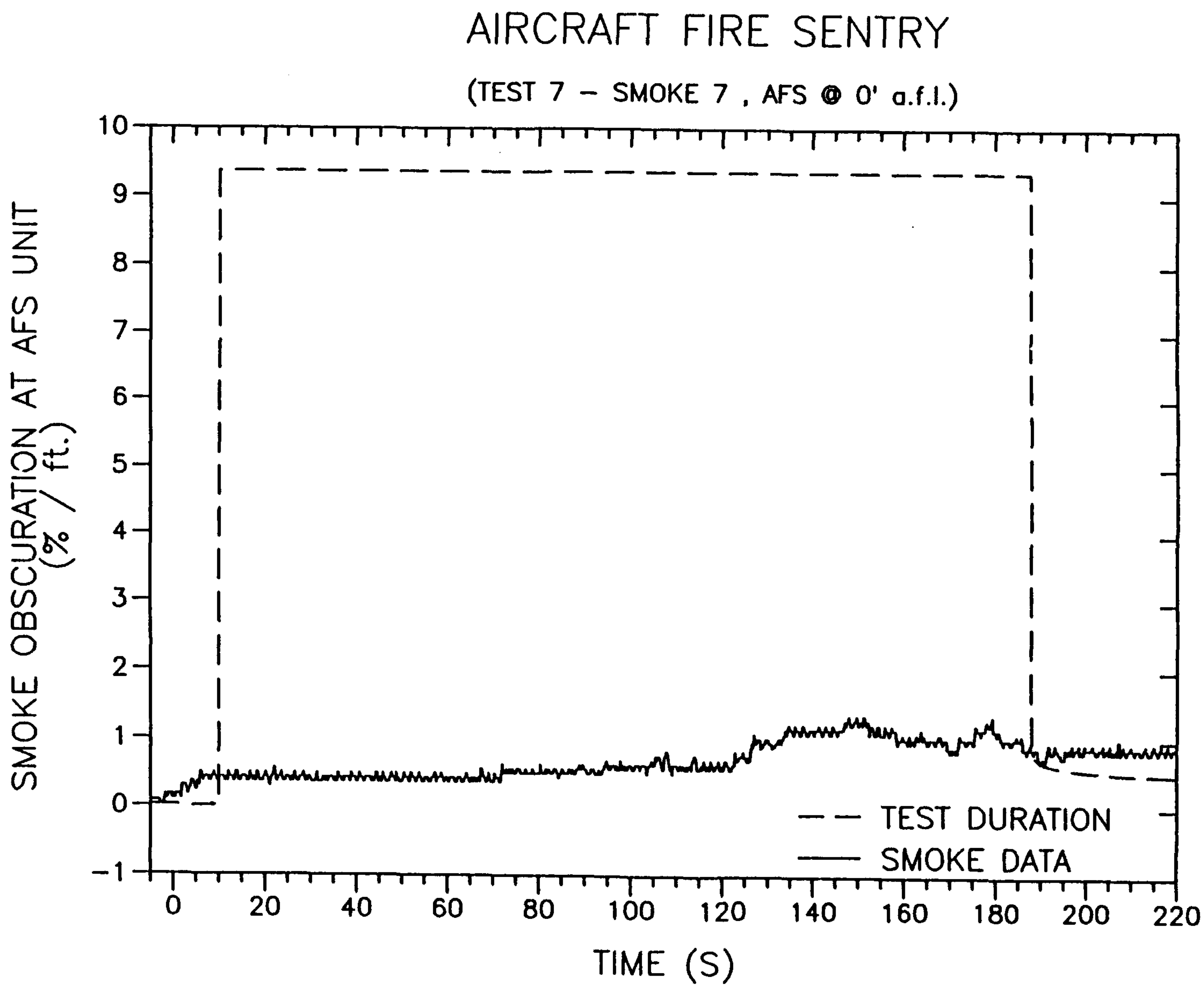


Figure B-15. Smoke Obscuration Near AFS vs. Time - Test 7

Test 8 (Smoke Test 8): BT2-3 was placed on the floor. Ambient temperature was 67°F. Time to alarm was 223 seconds. Obscuration levels at the BT2-3 were 0.8% at the time of alarm (see Figure B-16). RF link operated properly.

Post test it was discovered that smoke was emanating from inside the BT2-3 unit. When opened, charred battery wiring was found. During this test, the wiring overheated and burned off its insulating jacket. It is suspected that prolonged simultaneous operation (150 seconds or more) of the strobe, audible horn and transmitter drew too much current through the UL 1007, 22 gauge wire. Before further testing, the damaged wire was replaced with a 16-gauge, Type E, 200°C high-temperature wire. This problem was not re-encountered after the repair.

Test 9 (Smoke Test 9): BT2-3 was placed at ceiling height, 9.5 feet above floor level. Ambient temperature was 44°F. Time to alarm was 39 seconds. Problems with one of the digital recorders resulted in no data for obscuration near the BT2-3. However, hand recorded values indicate levels of 42% obscuration per foot near the BT2-3 at the time of alarm. The correct alarm message was received at the central Tx/Rx.

Test 10 (Smoke Test 10): BT2-3 was placed at ceiling height, 9.5 feet above floor level. Ambient temperature was 45°F. Time to alarm was 35 seconds. Hand recorded data indicates 22.5% per foot obscuration at the BT2-3 at the time of alarm. The alarm message was received at the central Tx/Rx via RF link.

Test 11 (Smoke Test 11): BT2-3 was placed at ceiling height, 9.5 feet above floor level. Ambient temperature was 45°F. Time to alarm was 53 seconds. Smoke obscuration was recorded and calculated to be 39% per foot near the BT2-3 at the time of alarm (see Figure B-17). The correct alarm message was received at the central Tx/Rx.

The fuel source for live fire testing consisted of materials that would simulate materials which could be found in an aircraft cargo bay. Strips of mattress padding had kerosene and motor oil poured over them. As the mixture was lit, the kerosene readily ignited the padding, producing flame while the burning oil produced smoke. Identical quantities of each material were used for all live fire tests.

In addition to the timing and smoke obscuration instrumentation used during the previous smoke testing, three separate temperature measurements were also recorded at three different locations during the live fire testing - one near the fire source, one near the BT2-3, and the third centered between the first two. Only very small temperature increases were seen on the middle temperature sensor. Temperature records for the sensor near the fire source ranged between 98°F and 441°F depending on whether the flames came into contact with the thermocouple. Average temperature of the environment near the fire was 171°F. The most applicable temperature data was gathered near the BT2-3. These are of interest in determining which detector on the BT2-3 (smoke or heat) triggered the alarm. Results of the IR

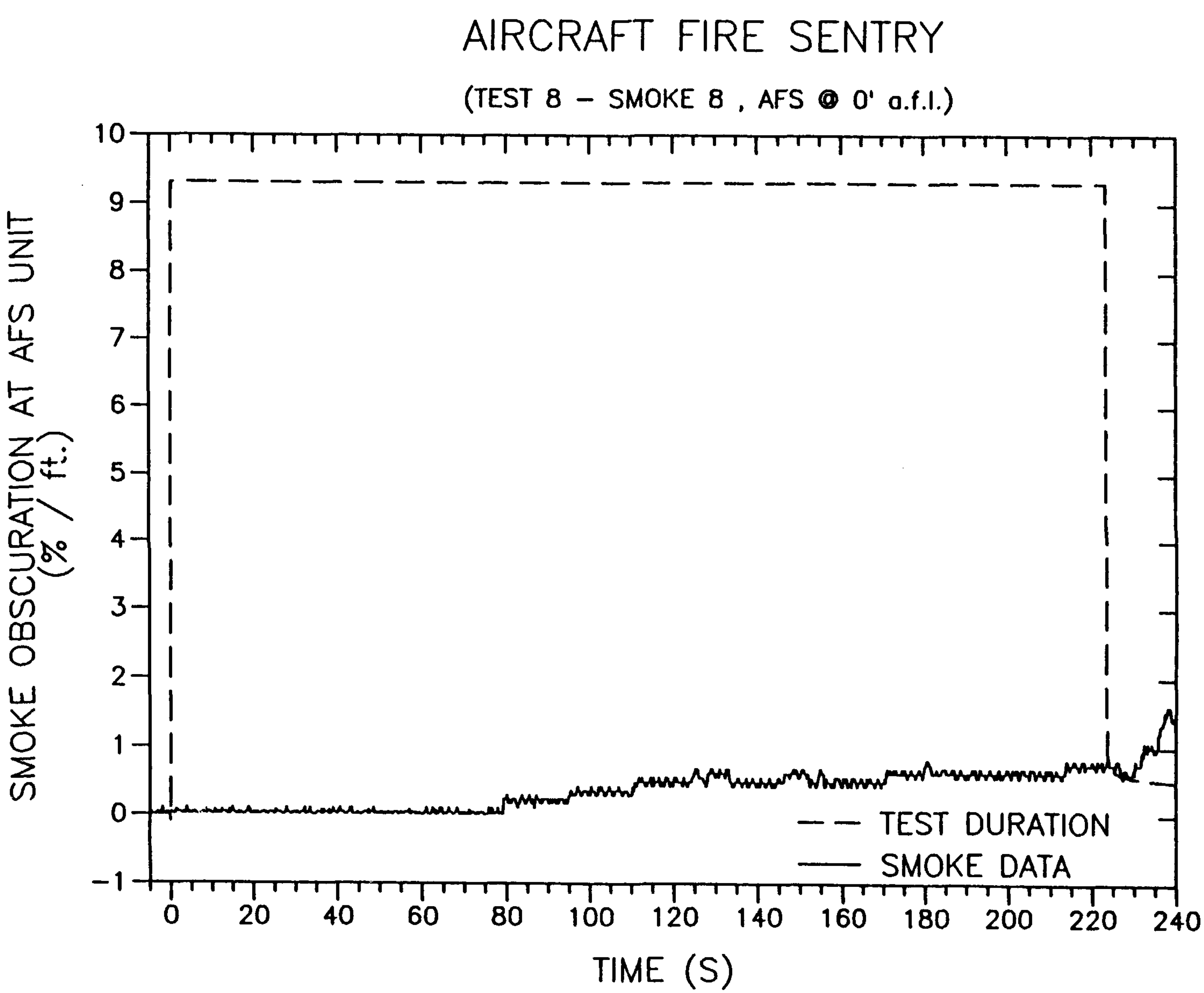


Figure B-16. Smoke Obscuration Near AFS vs. Time - Test 8

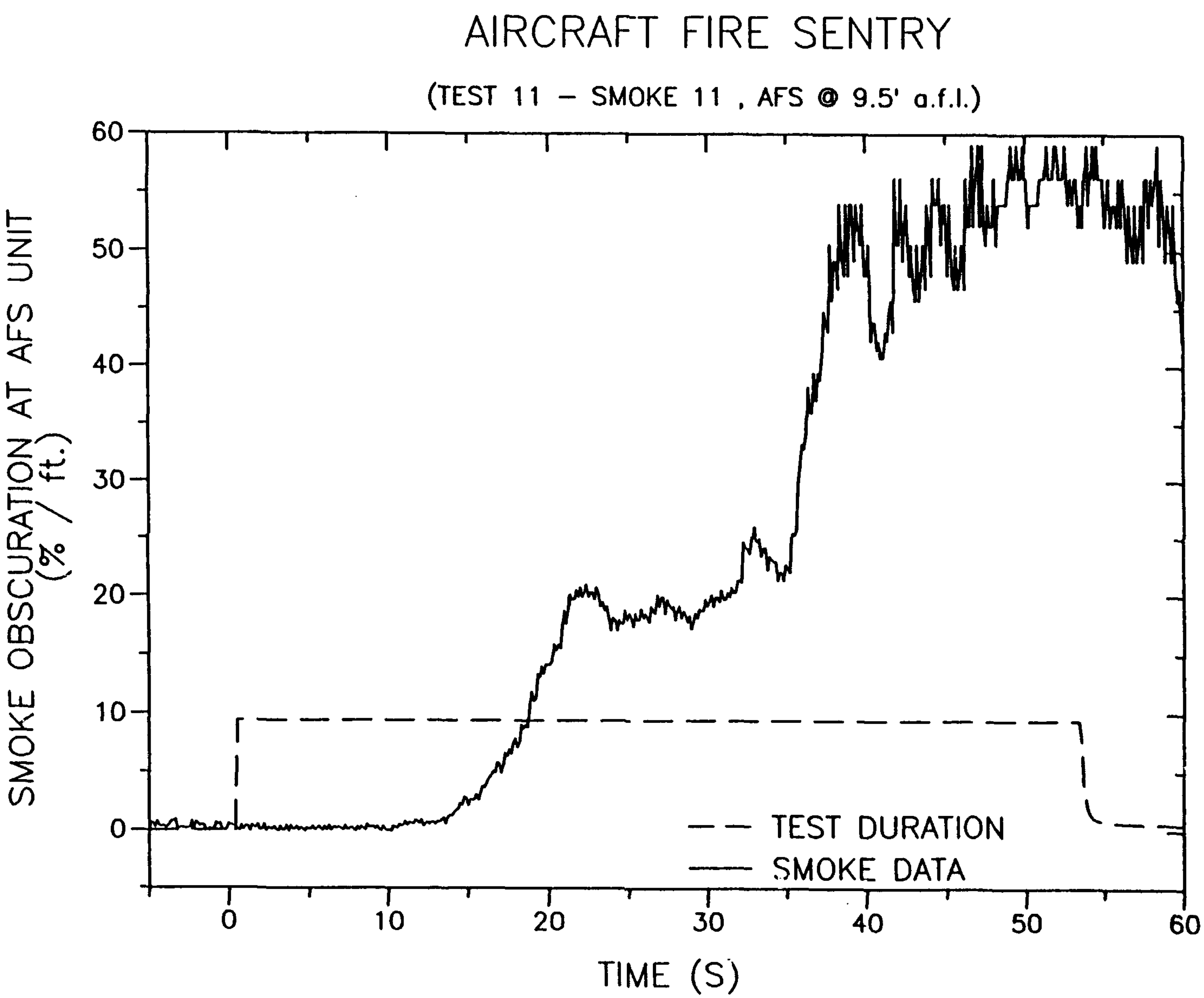


Figure B-17. Smoke Obscuration Near AFS vs. Time - Test 11

photography indicate IR levels so low in the vicinity of the AFS unit that no useful information was collected by this method.

Test 12 (Fire Test 1): BT2-3 was placed at ceiling height, 9.5 feet above floor level. Ambient temperature was 42°F. Time to alarm was 13 seconds. Smoke obscuration at the BT2-3 measured 2.6% per foot at the time of alarm. Temperature near the BT2-3 over the Time to alarm increased from 42°F to 82°F (see Figures B-18 and B-19). The correct alarm message was received at the central Tx/Rx.

Test 13 (Fire Test 2): BT2-3 was placed at 6 feet above floor level. Ambient temperature was 42°F. Time to alarm was 23 seconds. Values of smoke obscuration at the BT2-3 were 1.5% per foot (hand recorded). Temperature near the BT2-3 reached 78°F (see Figures B-20 and B-21). Alarm message was received at the central Tx/Rx.

Test 14 (Fire Test 3): BT2-3 was placed 3 feet above floor level. Ambient temperature was 42°F. Time to alarm was 72 seconds. Obscuration levels of 3.0% per foot (hand recorded) and 3.8% per foot (digitally recorded) were measured at the BT2-3 at the time of alarm. Temperature near the BT2-3 rose to 63°F (see Figures B-22 and B-23). The correct alarm message at the central Tx/Rx was received via RF link.

Test 15 (Fire Test 4): BT2-3 was placed at floor level. Ambient temperature was 42°F. Time to alarm was 137 seconds. Smoke obscuration at the BT2-3 was measured to be 6.5% per foot (hand recorded) and 6.1% per foot (digitally recorded) at the time of alarm. Temperature near the remote Tx/Rx rose to 57°F (see Figures B-24 and B-25). The alarm message was received at the central Tx/Rx.

The live testing indicates a quicker system response to real fires versus the simulated smoke-only sources. This could be the result of the fire causing the air to circulate inside the structure and essentially force smoke onto the detector. Smoke particle size is another factor. Live fires resulted in a coating of soot. The commercial smoke generators left no noticeable residue; thus, it is reasonable to suspect that the smoke detector took longer to react to the generators smoke particle size.

A graph showing response time and obscuration versus AFS height for the live fire testing is shown in Figure B-26. This graph shows the importance of keeping the AFS at a high location inside the cargo bay. System response time is quicker at approximately six feet and above, and measured smoke density levels are decreased.

All of the digitally recorded data can be found in Annex C.

Photographs of AFS hardware and the layout of equipment during selected tests can be found in Annex D.

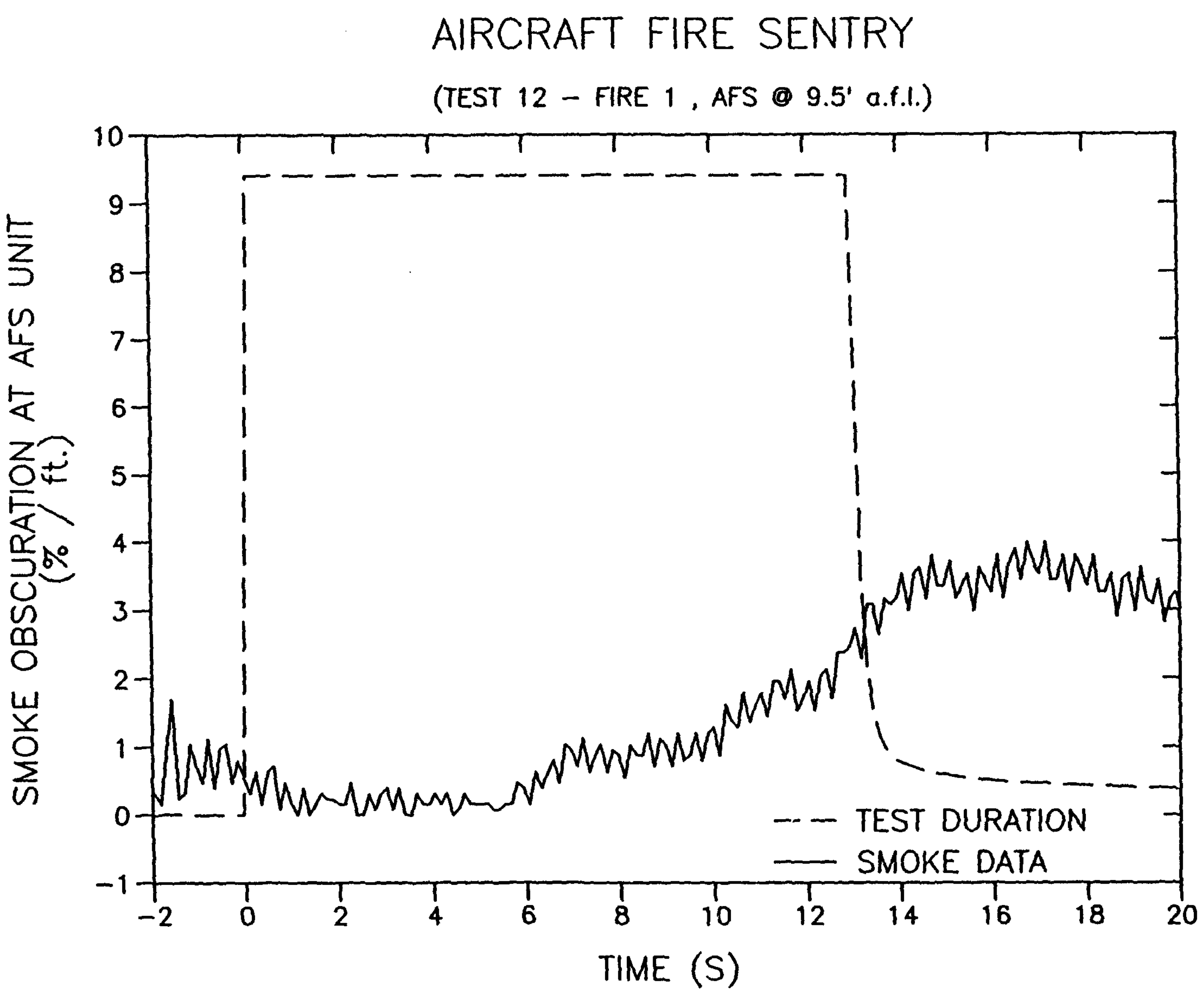


Figure B-18. Smoke Obscuration Near AFS vs. Time - Test 12

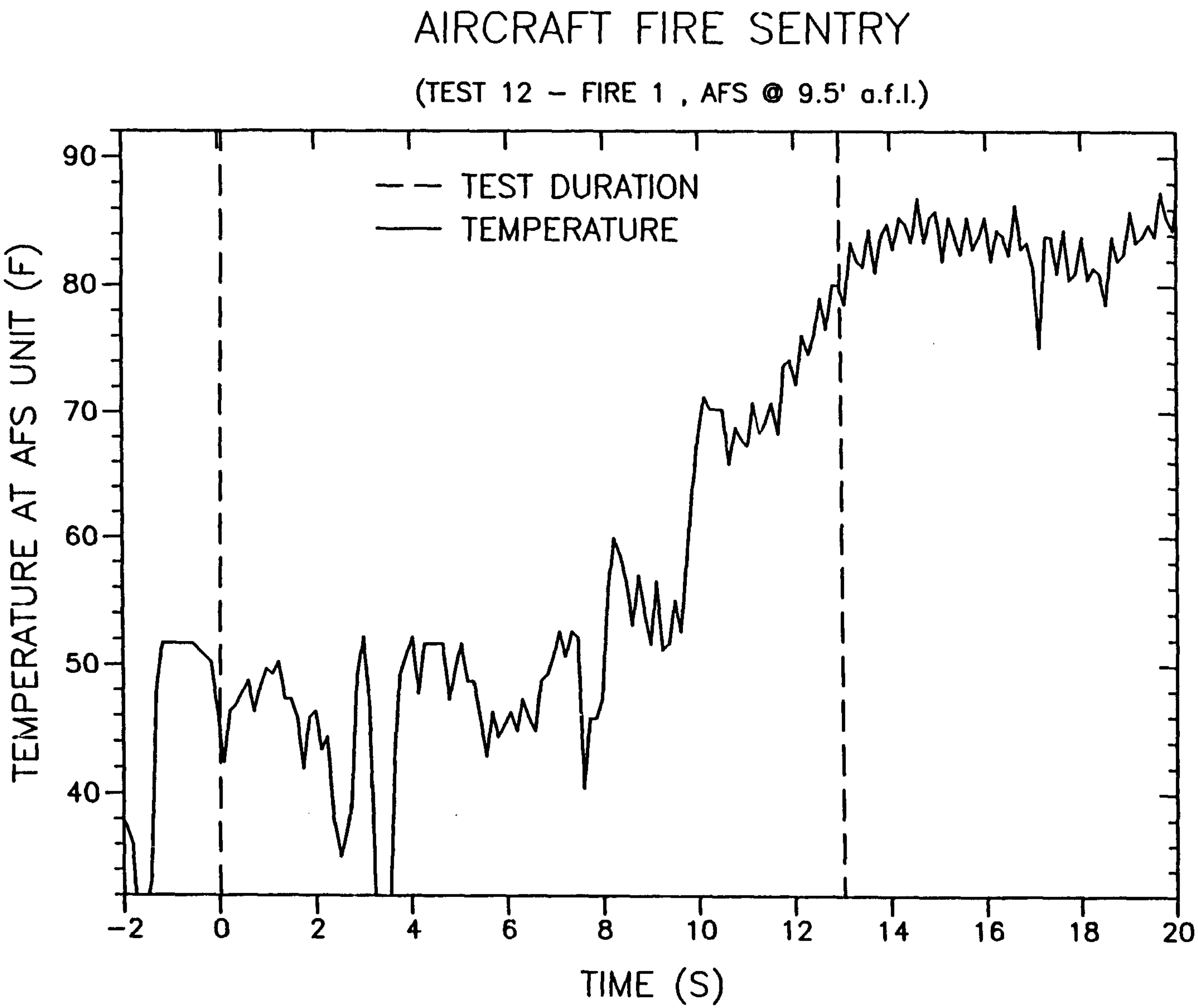


Figure B-19. Temperature Near AFS vs. Time - Test 12

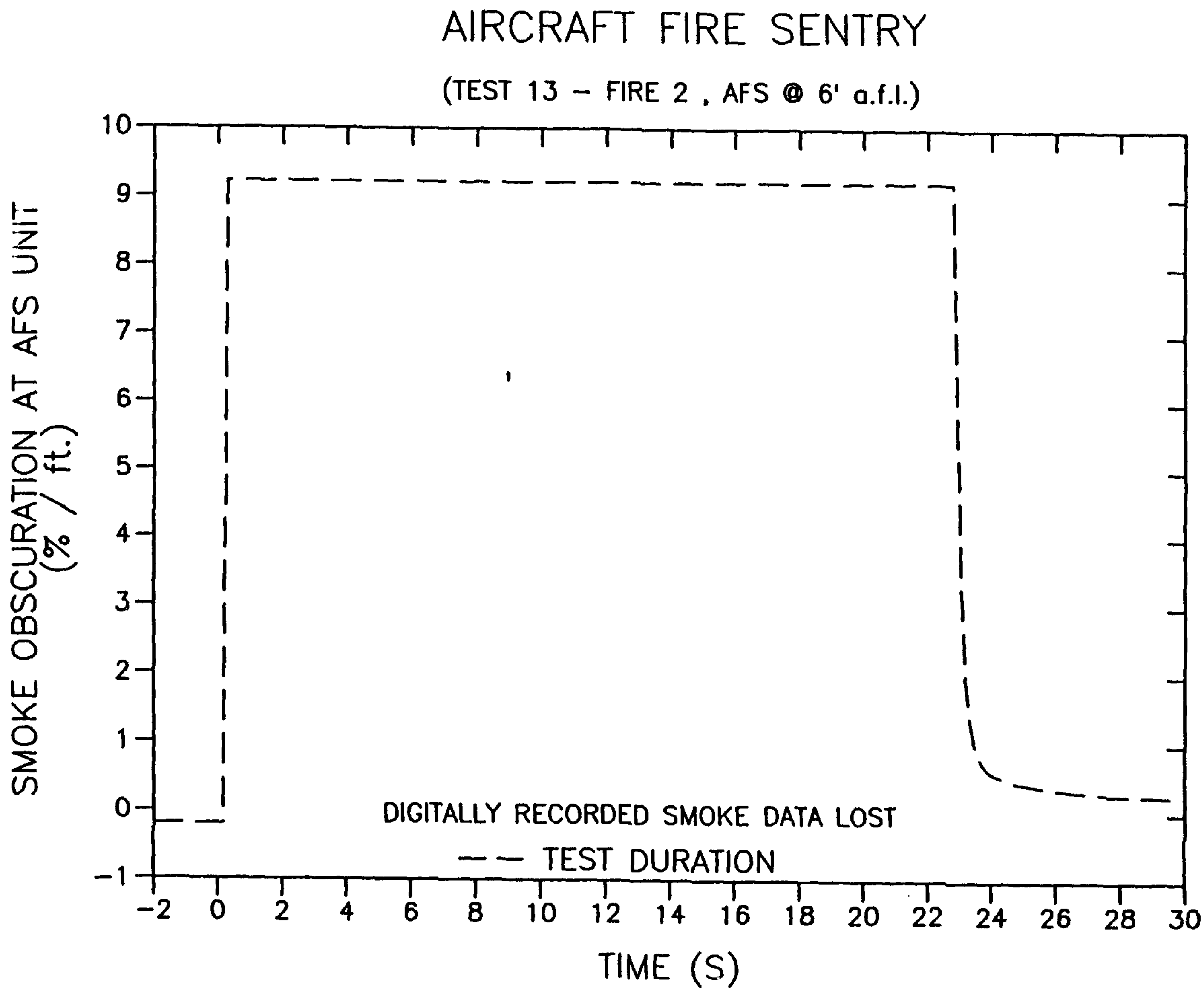


Figure B-20. Smoke Obscuration Near AFS vs. Time - Test 13

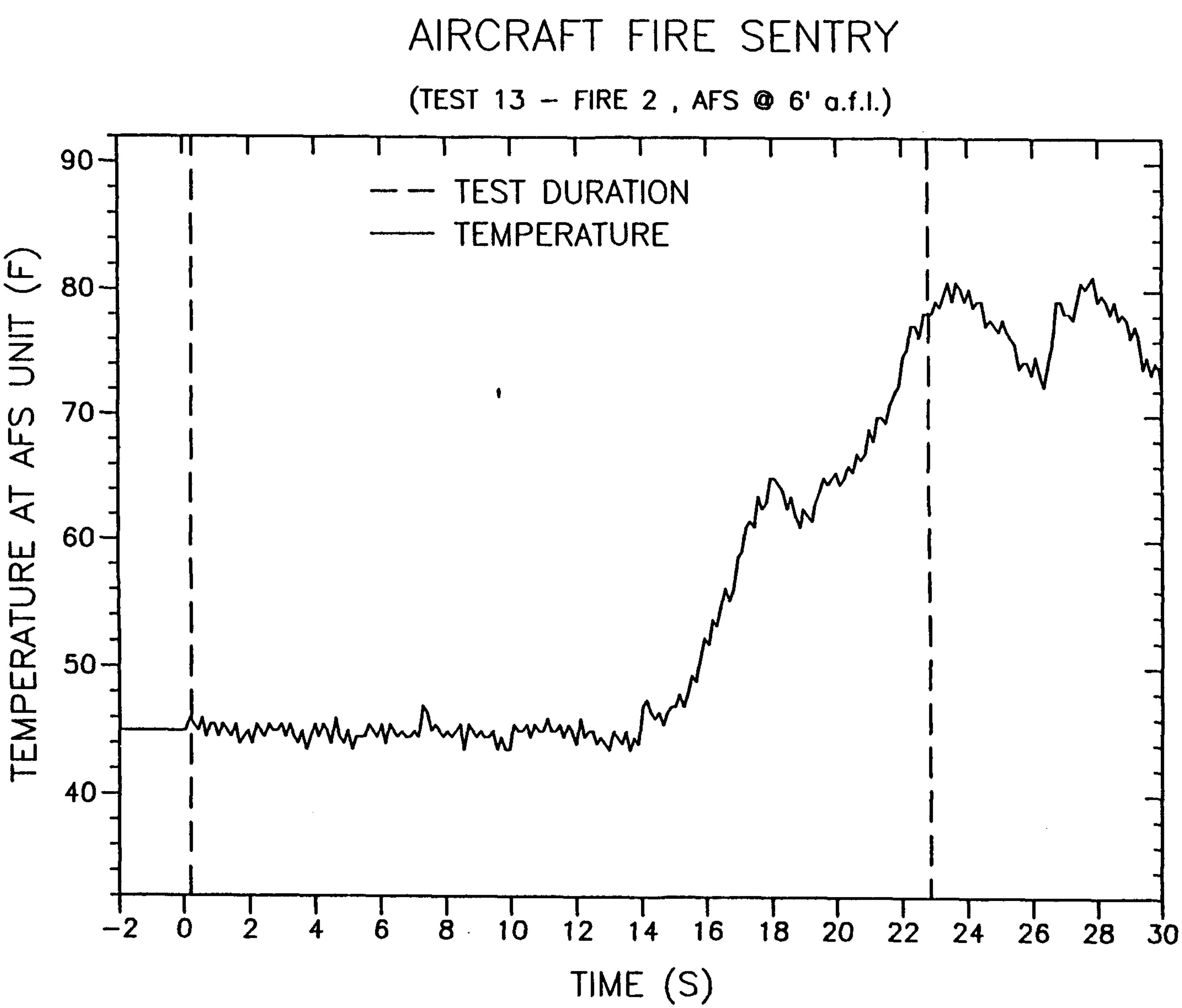


Figure B-21. Temperature Near AFS vs. Time - Test 13

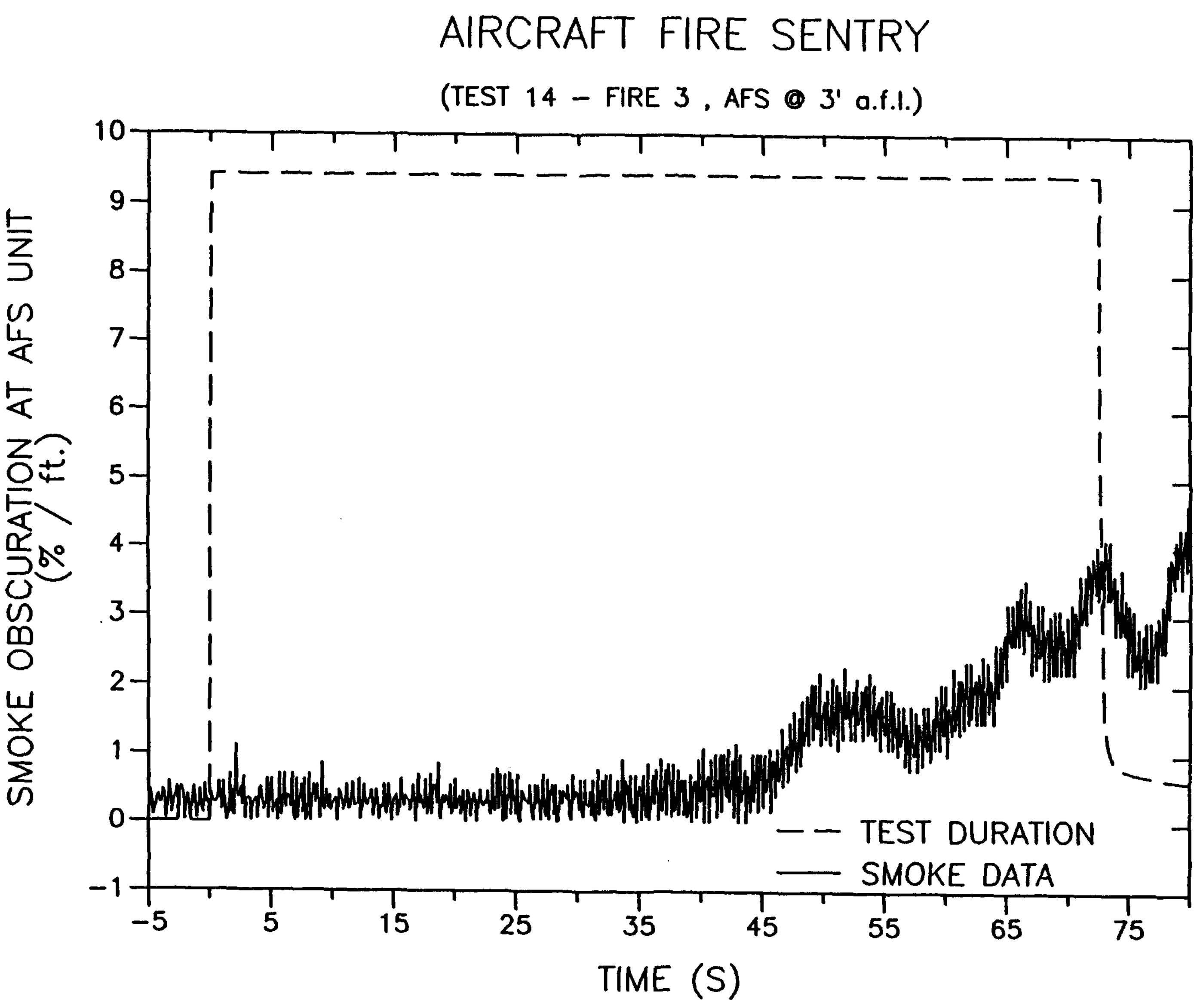


Figure B-22. Smoke Obscuration Near AFS vs. Time - Test 14

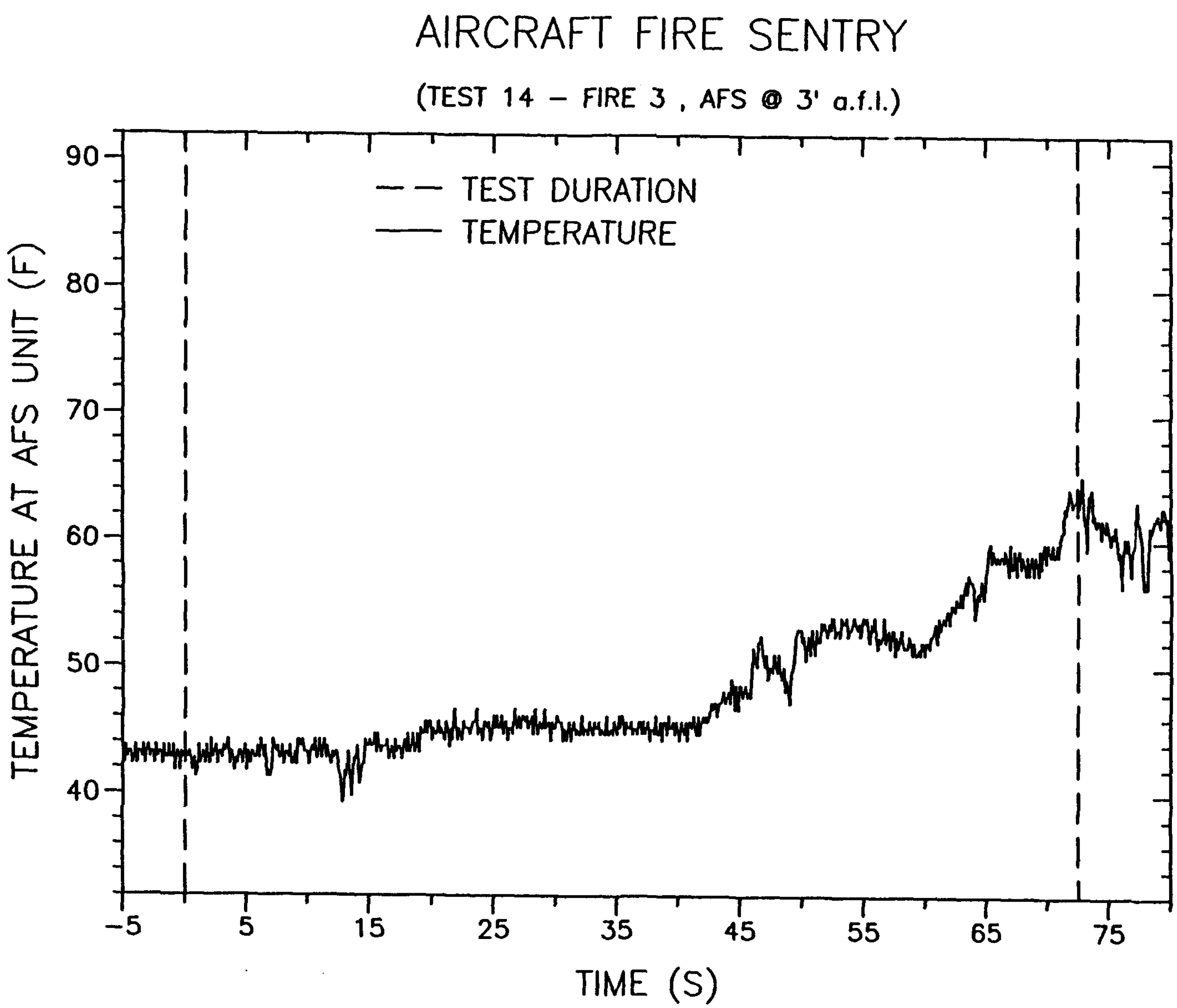


Figure B-23. Temperature Near AFS vs. Time - Test 14

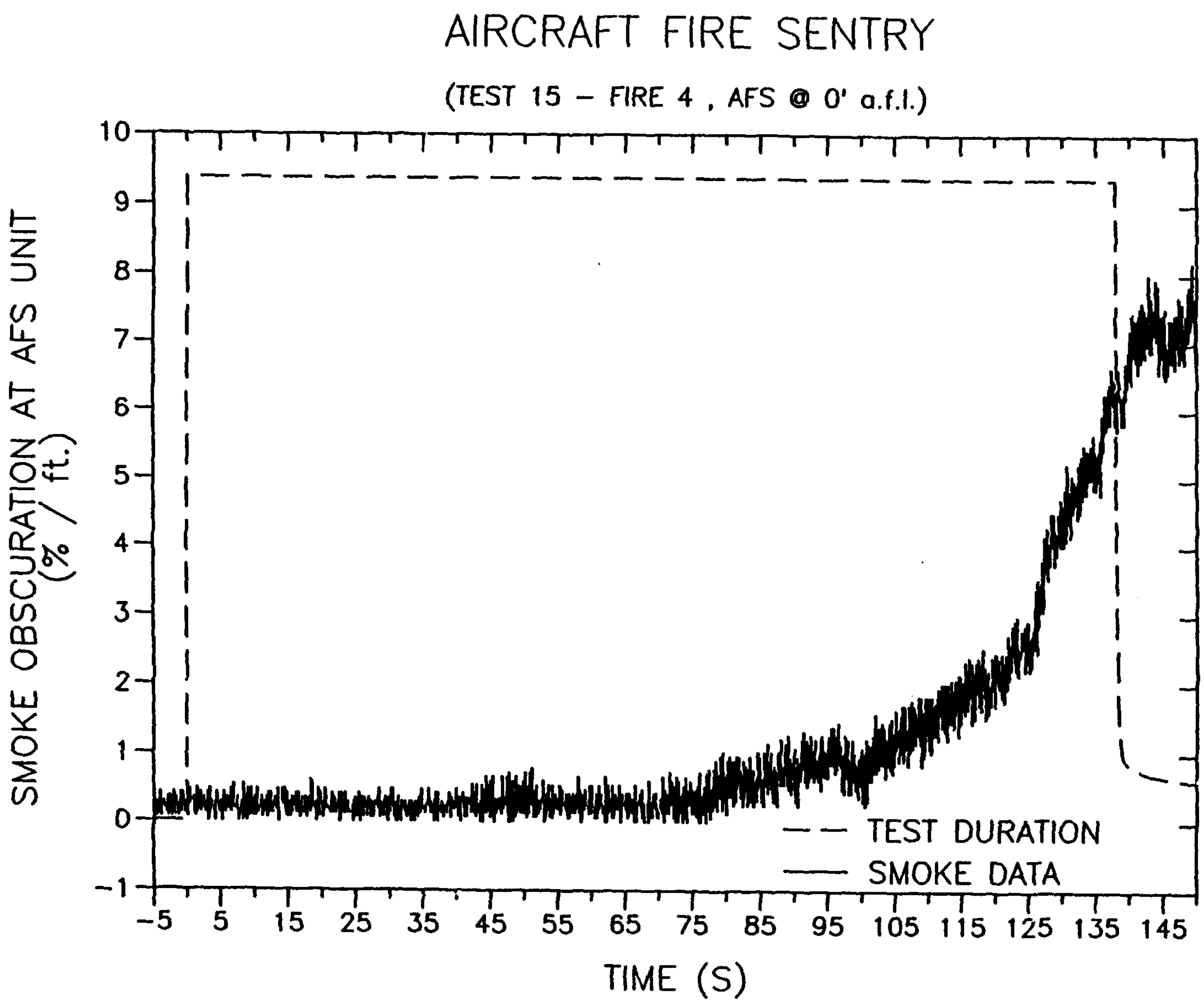


Figure B-24. Smoke Obscuration Near AFS vs. Time - Test 15

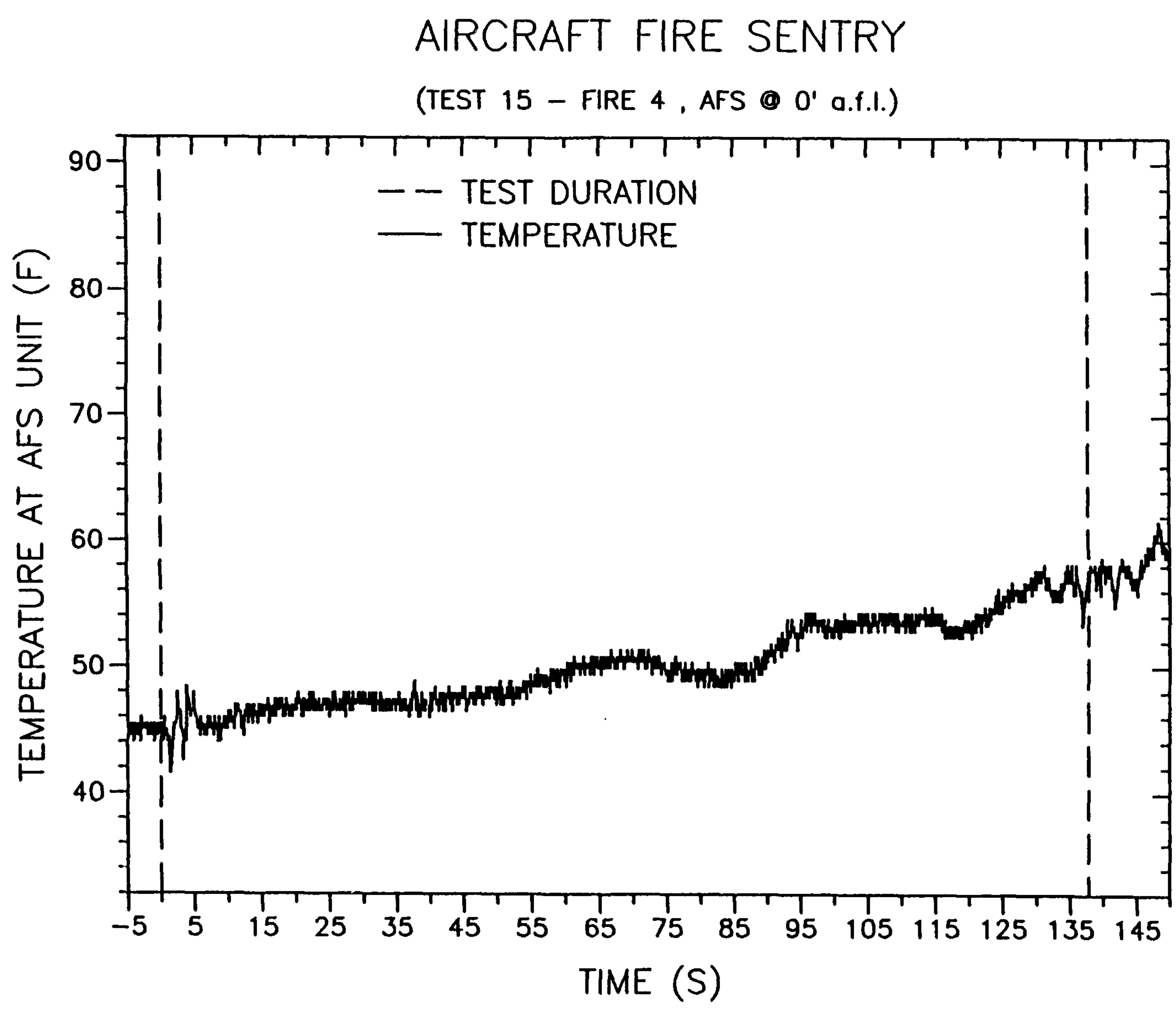


Figure B-25. Temperature Near AFS vs. Time - Test 15

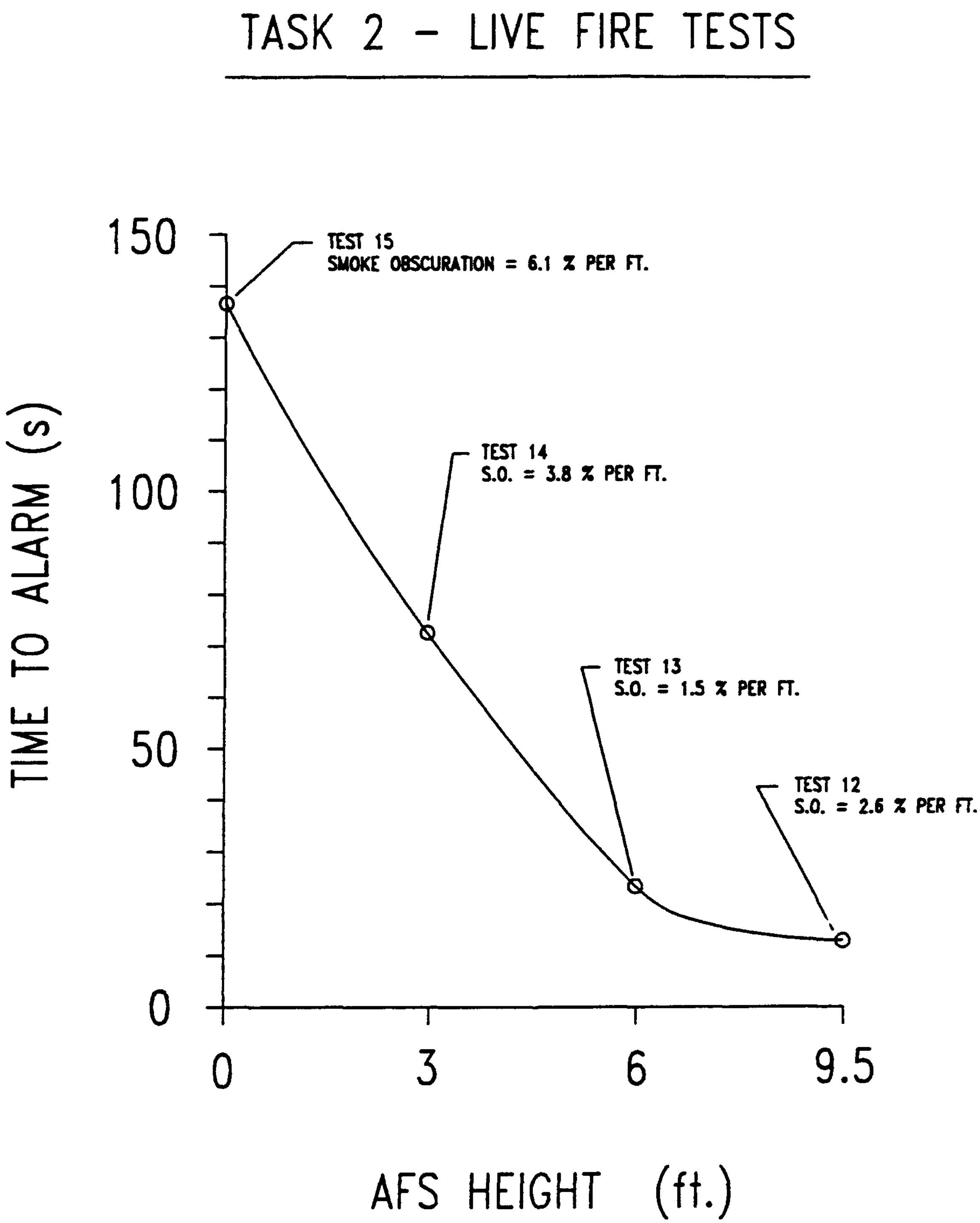


Figure B-26. Response Time and Obscuration vs. Height - Fire Tests

6.0 CONCLUSIONS

This design of the current AFS concept hardware has passed all tests required to demonstrate functional operation. The BT2-3 never failed to detect fire or smoke stimulus or notify the central Tx/Rx.

The live testing indicates a quicker system response to real fires versus the simulated smoke-only sources. Possible causes were discussed in Section 5.4. Because the smoke generators are not a good simulation of the smoke of actual fires, they will not be used during any additional performance testing of the AFS system.

Based on temperature records of the thermocouple placed near the BT2-3, the smoke detector triggered the alarm each time during the live fires.

Response times show that the best location for the BT2-3 is as high as possible. This creates, however, a couple of operational problems. When positioned high, the unit cannot be reached without a stepladder, which makes it difficult to monitor or to use the manual pull if required.

The system will operate on DC power, unattended for at least 60 hours in the modified four-battery configuration. The batteries must be verified fully charged (12 V+) prior to a 60 hour anticipated use. Verification of operation below 32°F or above 80°F was not conducted.

The manual pull station operated properly; however, it cannot be reached without a stepladder when the AFS unit is at ceiling height.

The heat sensor tests show that the unit will alarm when exposed to a heat-only source. However, it was observed during testing that the heat sensor triggered at an average temperature of 176°F during the testing and not at its rated 135°F.

The strobe operated during each alarm condition, but was obscured by smoke during many of the smoke tests and could not be seen at a distance of twelve feet.

The audible horn operated as expected every time.

7.0 COST OF THE CURRENT AFS CONCEPT CONFIGURATION

The production cost of the AFS discussed in this report in terms of hardware and assembly labor is as follows:

remote Tx/Rx	-	Monaco BT2-3	$ 2,799.00
	-	Modification hardware	397.00
	-	Modification labor, bench test, shipping	1,000.00
			$ 4,196.00 / unit
central Tx/Rx	-	with operating software and DC power supply	$20,000.00

8.0 RECOMMENDATIONS AND PROTOTYPE DESCRIPTION

Future AFS designs would benefit from the additional technical and operational recommendations. All of the comments pertain to the small scale remote Tx/Rx (BT2-3) unit and were formulated as a direct result of the test series described in previous sections of this report.

The AFS prototype should have the same operating principles as the Task 2 model. It will transmit alarm messages to a central Tx/Rx by a VHF radio frequency signal as a result of any of its detectors sensing a smoke or fire condition. An audible alarm will sound and a strobe will flash on the aircraft in trouble.

There are two main issues which are the foundation of the majority of the changes for the prototype. First, the ideal location for the remote unit is as high as possible inside the cargo bay. In all cases, this puts the unit out of normal reach which makes it difficult to monitor or access during installation or in the event of an emergency. A solution is to place the BT2-3 (or similar prototype) unit at about 6.5 feet above the floor and sample the environment near the ceiling by means of an extended or tethered device. Options for this are presented in a features list below. The second issue that substantially reconfigures the remote unit is the location of the strobe and horn. It will be more effective to have these two items located outside the aircraft along with the antenna. This will aid the fire department or flight line personnel in finding the aircraft on fire and insure unobstructed VHF communications.

One change that would be particularly helpful to the person installing the system and the responding base fire department is the addition of zone switches on the outside of the box. This arrangement will allow the installer to address the location (zone) of the AFS unit by reference to the tail number of the aircraft in which it is placed.

The exterior of the box should be free from as many protruding components as possible. This will reduce the possibility of damage to these components during handling.

The overall size, shape, and weight may increase from the BT2-3 somewhat due to the new configuration of components associated with the remote unit.

The recommended features of the prototype AFS include:

- an appropriately sized, environmentally tight enclosure,
- similar electronics boards and transmitter/receiver modules as the small scale design (BT2-3),
- same operating frequency as small scale design (Tyndall = 138.925 Mhz),
- modular interior construction. Easy access removal and replacement of components. Possible card cage/edge connector arrangement,
- 10" x 10" x 4" space allocated for machine vision flame detection system. Although machine vision is still under development and will

not be installed, a UV flame detector will be used as a simulator. Cut one hole in a selected side of the enclosure and install an appropriate glass lens,

- a manual pull station,
- an exterior mounted master switch with a complete unit reset function,
- three exterior LED's to monitor: a) power on/off, b) low battery, and c) tamper/trouble,
- exterior switches for unit addressing,
- an AC recharging receptacle,
- 60 hour back-up battery capability with the possibility of a removable/rechargeable battery power pack,
- hook/strap type hardware for mounting the unit inside the aircraft,
- horn, strobe, and antenna assembly that will be easily mounted on the exterior of the aircraft and connected to the remote unit with cable (pre-wired plug in assemblies),
- smoke detection capability to sample air from one to fifteen feet from the remote unit. Options may include: a) "beam" detector system utilizing a telescoping assembly that can extend the emitter or receiver away from the box, b) separate photoelectric or fixed separation beam detector which could be hung at any height and connected to the remote unit with cable (pre-wired plug in assemblies),
- a compatible storage box for the remote assembly's loose components (i.e., smoke detector, horn/strobe, antenna, cabling).

All hardware inside the BT2-3 (or similar) unit should be secured so that nothing rattles or moves during handling. Commercial equipment will be used that has a standard environmental operating range of 32°F to 100°F.

APPENDIX B

ANNEX A

TASK 2 - TEST PLAN

AIRCRAFT FIRE SENTRY

Task 2 - Prototype System Test Plan

Prepared by:

Robert Mugele

Applied Research Associates, Inc.
7114 W. Jefferson Ave., Suite 305
Lakewood, Colorado 80235

Date: September 6, 1991

Revised: October 31, 1991

Prepared for:

Headquarters Air Force
Engineering Services Center,
Scientific and Engineering Technical Assistance (SETA)
Tyndall Air Force Base, Florida 32403

Contract Number F08635-88-C-0067
Supplemental Support Group Subtask (SSG) 3.14.1

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 SCOPE

This test plan shall be used to demonstrate the operation of the "small-scale breadboard" design of the Aircraft Fire Sentry (AFS) system.

1.2 OBJECTIVES

The objectives of the testing are: (1) to demonstrate the AFS system's ability to detect fires using smoke and heat detectors only; (2) determination of the optimal placement of the system, with respect to height above floor level in the (simulated) aircraft; (3) determination of the estimated time between fire/smoke initiation, detection, and notification of a remote receiver station, for a limited set of test conditions; and, (4) to verify correct operation of the AFS components, especially the system's ability to notify the fire department (the central transmitter/receiver) via an RF link.

1.3 APPLICABLE DOCUMENTS

Monaco Enterprises, Inc. Installation, Operation and Maintenance Manuals for the D-500 Plus Advanced Wireless Information Management Alarm Receiving and Reporting System, and the Monaco BT2-3 Building Transceiver.

Aircraft Fire Sentry Statement of Work (SSG 3.14.1).

1.4 TYPES OF TESTS

Four different types of tests shall be performed:

a. 60-Hour Operational Test,
b. Manual Pull Station Test,
c. Heat Detection Test,
d. Live Fire/Smoke Test.

1.5 FACILITIES

The 60-Hour, Manual Pull, and Heat Detection tests will be conducted in a laboratory at Applied Research Associates, Inc.'s Lakewood, Colorado office.

ARA has constructed a temporary test structure at its remote test facility, which is approximately 30 miles east of the Denver Metro area. Live fire and smoke testing will be conducted at this location.

1.6 AIRCRAFT FIRE SENTRY (AFS) COMPONENTS

The AFS system essentially consists of a remote transmitter/receiver station which has been modified to include a heat/smoke detector, manual pull station and strobe. This unit would be placed inside of parked cargo aircraft. It will be referred to as the Remote Tx/Rx, or RTR in this test plan. It will be communicating its status by radio frequency link to a central transmitter/receiver station. This later unit would generally be located at the base fire department. In this test plan, it will be referred to as the Central Tx/Rx, or CTR.

The Remote Tx/Rx basic unit is a Monaco BT2-3. The Central Tx/Rx is a Monaco D-500 Plus. All tests conducted under this test plan will be carried out using 50 Ohm dummy load antennas in place of the BSA-1 VHF Omnidirectional Antenna Assembly.

During all testing, the AFS Remote Tx/Rx will be operating on its own internal battery power. Battery voltage will be checked after each test and recharged as necessary.

2.0 TEST DESCRIPTIONS

2.1 60-HOUR OPERATIONAL TEST

The objective of this test is to verify the requirement that the AFS system must be capable of continuous stand-alone operation for a minimum of 60 hours.

The unit under test will operate on its own internal battery power for the duration of this test. The batteries will be verified fully charged at the beginning of the test and will not be recharged until the test is over.

Instrumentation required:

a. AFS Remote Tx/Rx
b. AFS Central Tx/Rx
c. 35mm camera
d. Voltmeter

Outline of test procedure:

1. The 35 mm camera will be used to photo-document the event.
2. Verify the batteries in the RTR unit are fully charged with voltmeter.
3. Verify the RF communication link between the RTR and the CTR stations by pulling the manual alarm handle and monitoring the CTR response.
4. Record time, date, and ambient temperature at the beginning of the test.
5. Leave unit on, under battery power for 60 hours.
6. Record time, date and system responses at the 60-hour mark.
7. Verify duration of operation.

If battery power still checks good, continue test Steps 5 and 6 to determine ultimate duration for the given test conditions (ambient temperature). Check unit every two hours when practical. Recharge and repeat 60-hour test one time.

2.2 MANUAL ALARM TEST

The objectives of this particular test are to check operation of the manual pull station modification to the AFS unit and verify the system's ability to notify the CTR via the RF link.

For this test, all equipment will be powered up, at which time the RTR will be interrogated for its status by the CTR station. This will verify the communication link. Then, the manual pull handle will be activated and the CTR receiver

monitored for the correct alarm message. A stopwatch will be used to determine elapsed time from pull to receiver notification. The handle will then be returned to its "normal" position. The CTR station will be monitored for the "all normal" signal to be sent.

Instrumentation required:

a. AFS Remote Tx/Rx
b. AFS Central Tx/Rx
c. 35 mm camera
d. stopwatch
e. video camera

Outline of test procedure:

1. Photo-document event components.
2. Power up the AFS system components.
3. Using CTR station, interrogate the Remote unit to verify communication.
4. Activate manual pull handle.
5. Document response from CTR.
6. Measure response time.
7. Restore handle to normal position.
8. Document response from CTR.

Repeat test 2 times.

2.3 HEAT TEST

This test is designed to verify the AFS system's ability to sense an overheating condition due to a fire, and then transmit the proper alarm message via the RF link.

For this test, the Remote Tx/Rx will be subjected to a non-smoking, radiating heat source. The temperature shall be increased until the heat sensor triggers the alarm and transmits its message. A temperature thermocouple will be mounted to the face of the detector to measure the temperature of the environment. The installed heat sensor is rated to trigger an alarm at 135°F.

Instrumentation required:

a. AFS Remote Tx/Rx
b. AFS Central Tx/Rx
c. Radiating heat source
d. Temperature probe
e. 35 mm camera
f. Video

Outline of test procedure:

1. Photo-document test setup and equipment with the 35 mm camera.
2. Verify the Remote and Central Tx/Rx stations are powered up and operational.
3. Verify the RF communication link between the two.
4. Video record the test event.
5. Record initial temperature of environment before heat is applied.
6. Slowly apply heat source to the detector until strobe turns on and alarm message is sent.
7. Record temperature and remove heat source.
8. Verify Central Tx/Rx has received the correct alarm message.

Let the detector cool, reset all equipment, and repeat the test.

2.4 LIVE FIRE/SMOKE TEST

The objectives for these tests are to demonstrate the operation of the AFS system under actual live fire/smoke conditions. These tests shall demonstrate the system's ability to detect and report fires using smoke and heat detectors only, aid in the determination of the optimal placement of the system in an aircraft, and provide data as to the expected elapsed time between fire detection and fire reporting.

A minimum of eight separate tests will be conducted. The eight will be divided into two groups of four. The first group will test the AFS system against non-heat-producing smoke sources. The second group will test the AFS system under real fire conditions. Tests 1 through 4 of each group will have the AFS Remote Tx/Rx placed at a different height with respect to floor level. One test will be conducted at floor level, one at three feet, one at six feet, and one at the ceiling which is approximately ten feet above floor level. The fire/smoke source will be ignited in a steel tray which is against the opposite wall from the AFS unit. Horizontal distance between walls will be twelve feet.

Commercial smoke generators will be used during smoke tests. When lit, each generator produces 4000 cubic feet of grey/white smoke in approximately 30 seconds.

Live fires will be ignited using a combination of kerosene, motor oil, and fabric padding. These materials would simulate a typical potential fire hazard in a cargo bay.

Smoke density measurements will be taken which will be converted to percent obscuration per foot. One measurement near the live fire/smoke source will

quantify output near the source. Another measurement will monitor the smoke near the AFS Remote Tx/Rx.

Three temperature sensors will also monitor the environment during live fire tests. One temperature thermocouple will be placed near the source, one on the face of the AFS heat detector, and one on line of sight centered between the two. The heat detector should go into alarm when 135^{o}F is reached at its sensor. A heat only test is carried out as its own unique test and described in Section 2.3.

All smoke density and temperature measurements will be recorded by Digistar II digital recording equipment. Time duration of each test, from ignition to alarm, will also be recorded.

A 35 mm camera will be used pre-test for photo documentation. A video camera will be used to record each test. During the live fire tests, a 35 mm SLR camera with IR film will be used to take pictures around the AFS Remote Tx/Rx.

Instrumentation required:

a. AFS Remote Tx/Rx
b. AFS Central Tx/Rx station
c. Smoke density measurement systems
d. Temperature measurement systems
e. Data recording equipment
f. 35 mm camera
g. 35 mm camera (IR film)
h. Video camera
i. Smoke generators
j. Self-contained breathing apparatus (SCBA)
k. Heat source

Outline of test procedure:

1. Photo-document test setup with 35 mm camera.
2. Verify all battery powered equipment is fully charged and operational.
3. Verify all AC powered equipment is operational.
4. Verify RF communication link is established between AFS Remote and Central stations.
5. Verify IR and video cameras are ready.
6. Verify SCBA and fire extinguishers are ready.
7. Start video.
8. Document all initial data parameters.
9. Ignite fuel/smoke source.
10. Begin test data recorders.
11. Let test run until alarm condition.
12. Turn off data recorders.

13. Extinguish fire/evacuate smoke.
14. When clear, reset all equipment and configure for next test.

3.0 TEST DATA RECORDS

The following data sheets shall be used to record data taken during the testing of the Aircraft Fire Sentry System.

3.1 60-HOUR OPERATIONAL TEST RECORD

Date: ___________
Time: ___________

Test Operator: ___________________________
Others present to participate in, or witness test:

____
____
____

Test Location: ___________________________

1. Photo-document. _____
2. Verify batteries charged. _____
3. Verify operation and RF link. _____
4. Record time, date, and temperature at beginning of test. _____
5. Operate for 60 hours. _____
6. Record time and date, verify 60 hour operation. _____
7. Record total operating time (if applicable). _____

Test notes:

3.2 MANUAL ALARM TEST RECORD

Date: __________
Time: __________

Test Operator: ________________________
Others present to participate in, or witness test:

____
____
____

Test Location: __________________________

1. Photo-document. _____
2. Power up components. _____
3. Interrogation status of Remote Tx/Rx by CTR. _____
4. Activate handle. _____
5. Document response by the CTR. _____
6. Record response time. _____
7. Restore handle to normal. _____
8. Document response by the CTR. _____

Test notes:

3.3 HEAT TEST RECORD

Date: __________
Time: __________

Test Operator: ________________________
Others present to participate in, or witness test:

____
____
____

Test Location: ________________________

1. Photo-document. ____
2. Verify Remote and Central Tx/Rx operational. ____
3. Verify RF link. ____
4. Turn on video system. ____
5. Record temperature. ____
6. Apply heat source. ____
7. Note temperature at alarm initiation. ____
8. Check Central Tx/Rx for correct message. ____

<u>Test notes:</u>

3.4 LIVE FIRE/SMOKE TEST RECORD

Date: ____________
Time: ____________
Test Operator: ______________________________
Others present to participate in, or witness test:

______________ ______________

______________ ______________

______________ ______________

Test Location: ______________________________
Live Test Number: ____________________________
Fire/Smoke Source: ___________________________
AFS height above floor: ________________________

1. Photo-document configuration. ____
2. Verify all batteries charged and equipment operational. ____
3. Verify all AC equipment operational. ____
4. Verify RF link. ____
5. Verify IR and video cameras ready. ____
6. Verify SCBA and fire extinguishers ready. ____
7. Begin IR and video cameras. ____
8. Document initial instrumentation data parameters. ____
9. Ignite fuel source. ____
10. Trigger data recorders. ____
11. Wait for alarm. ____
12. Shut off recorders. ____
13. Extinguish fire/evacuate smoke. ____
14. Reset equipment and reconfigure. ____

<u>Test notes:</u>

APPENDIX B

ANNEX B

This annex contains the test records that are a part of the test plan. There is a completed test record for each one of the 25 separate functional tests of the AFS system.

3.1 60-HOUR OPERATIONAL TEST RECORD

Date: 11-01-91
Time: 8:00 pm

Test Operator: Robert Mugele
Others present to participate in, or witness test:

None

Test Location: Applied Research Associates, Inc. RMD office

1.	Photo-document.	X
2.	Verify batteries charged.	X 12.8 VDC
3.	Verify operation and RF link.	X
4.	Record time, date, and temperature at beginning of test.	X 72°F
5.	Operate for 60 hours.	X
6.	Record time and date, verify 60 hour operation.	X 11-04-91 8:00 am
7.	Record total operating time (if applicable).	See Note 7

Test notes:

1. RF link verified 3 ways:
   a. BT2-3 Self-test
   b. Manual pull station
   c. D-500 interrogation
2. Low bat LED was on at 60 hours. Voltage measured 11.58 VDC.
3. RF link was still operational at 60 hours, so test was continued to determine ultimate duration. The unit was checked every 2 hours after 60 for the remainder of the workday (11-04-91).
4. The last good check of the system occurred at 4:00 pm on 11-04-91.
5. The system was not responding at 9:00 am on 11-05-91 under any type of self test or interrogation. Battery voltage was measured at 6.95 VDC.
6. The test was successfully completed at 60 hours, conducted under ambient conditions of 70°F.
7. Ultimate duration of the batteries was between 68 and 83 hours at 70°F.

3.1 60-HOUR OPERATIONAL TEST RECORD

Date: 11-15-91

Time: 8:00 pm

Test Operator: Robert Mugele

Others present to participate in, or witness test:

None

Test Location: Applied Research Associates, Inc. RMD office

1.	Photo-document.	X
2.	Verify batteries charged.	12.84 before power up X 12.81 after
3.	Verify operation and RF link.	X
4.	Record time, date, and temperature at beginning of test.	X 73.8°F
5.	Operate for 60 hours.	X
6.	Record time and date, verify 60 hour operation.	X 11-18-91 8:00 a.m. 68.4°F
7.	Record total operating time (if applicable).	See Note 3

Test notes:

1. The modem in the CTR was operating intermittantly, but eventually began working reliably later in the evening. Remote unit signals were verified by a portable scanner and the CTR.
2. The test is successfully completed at 60 hours. Battery voltage is measured at 11.45 VDC.
3. Ultimate duration will not be determined this time in order to recharge and prepare for next tests.

3.1 60-HOUR OPERATIONAL TEST RECORD

Date: 11-26-91
Time: 2:30 pm

Test Operator: Robert Mugele
Others present to participate in, or witness test:

None

Test Location: Applied Research Associates, Inc. RMD office

1.	Photo-document.	None taken
2.	Verify batteries charged.	X 12.8 VDC
3.	Verify operation and RF link.	X
4.	Record time, date, and temperature at beginning of test.	X 11-26-91 2:30 pm, 33°F
5.	Operate for 60 hours.	X
6.	Record time and date, verify 60 hour operation.	X 11-29-91 2:30 am 60 hrs.
7.	Record total operating time (if applicable).	X 11-29-91 4:00 pm 73.5 hrs.

Test notes:

1. AFS remote unit successfully operated for the 60 hours at refrigerated conditions of between 32° and 35°F.
2. "Low batt" message first appeared at 45 hours -- Batt = 11.74 VDC.
3. Battery voltage at 55 hours was 11.4 VDC.
4. The test ultimately went to 73.5 hours and was still responding although battery power was getting quite low -- 7.79 VDC.

3.2 MANUAL ALARM TEST RECORD

Date: 11-18-91
Time: 11:30 am

Test Operator: Robert Mugele
Others present to participate in, or witness test:

None

Test Location: Applied Research Associates, Inc. RMD office

1.	Photo-document.	X
2.	Power up components.	X
3.	Interrogation status of Remote Tx/Rx by CTR.	X
4.	Activate handle.	X
5.	Document response by the CTR.	X
6.	Record response time.	X
7.	Restore handle to normal.	X
8.	Document response by the CTR.	X

Test notes:

1. Batteries have been on charge all night and measure approximately 12 VDC.
2. Self test good, CTR interrogation good → RF link OK.
3. Test done 3 times with consecutive good results. Alarm and normal messages have come through correctly. Average time between handle pull and screen message/alarm about 6 seconds.
4. Manual pull modification to remote Tx/Rx is operational.
5. Video record of this test.

3.2 MANUAL ALARM TEST RECORD

Date: 11-18-91
Time: 2:00 pm

Test Operator: Robert Mugele
Others present to participate in, or witness test:

None

Test Location: Applied Research Associates, Inc. RMD office

1.	Photo-document. (Photos taken during prior test)	N/A
2.	Power up components.	X
3.	Interrogation status of Remote Tx/Rx by CTR.	X
4.	Activate handle.	X
5.	Document response by the CTR.	X
6.	Record response time.	X
7.	Restore handle to normal.	X
8.	Document response by the CTR.	X

Test notes:

1. Batteries good.
2. Self test and interrogation verify RF link.
3. First pull - CTR – ZID 101 alarm check. 5.25 seconds is the time from handle pulled to alarm at CTR. Restore handle to normal position - CTR – ZID 101 normal.
4. Three more tests conducted. All CTR responses were the same as first test. Times were 17.5, 4.75, 7.5, respectively.
5. The manual handle modification to the remote Tx/Rx has never failed to operate correctly except for when the batteries get low.
6. These tests have verified that the modification works and the messages can be communicated by RF.

3.3 HEAT TEST RECORD

Date: 11-19-91
Time: 11:45 am

Test Operator: Robert Mugele
Others present to participate in, or witness test:

Peter Dzwilewski

Test Location: Applied Research Associates, Inc. RMD office

1.	Photo-document.	X
2.	Verify Remote and Central Tx/Rx operational.	X
3.	Verify RF link.	X
4.	Turn on video system.	X
5.	Record temperature.	X 69°F
6.	Apply heat source (cigarette lighter).	X 00:53 min:sec
7.	Note temperature at alarm initiation.	X 120°F
8.	Check Central Tx/Rx for correct message.	X ZID102 Alarm

Test notes:

1. Successful test, everything operated normally, with the possible exception of the temperature at which the heat sensor goes into alarm. Sensor is advertised to trigger at 135°F. Our measurements have been 166°F for the previous test, and 120°F now.
2. There is a video record of this test.

3.3 HEAT TEST RECORD

Date: 11-19-91

Time: 1:30 pm

Test Operator: Robert Mugele

Others present to participate in, or witness test:

Peter Dzwilewski

Test Location: Applied Research Associates, Inc. RMD office

1.	Photo-document.	X
2.	Verify Remote and Central Tx/Rx operational.	X
3.	Verify RF link.	X
4.	Turn on video system.	X
5.	Record temperature.	X 71°F
6.	Apply heat source (portable electric heater).	X 2:19 min:sec
7.	Note temperature at alarm initiation.	X 200°F
8.	Check Central Tx/Rx for correct message.	X ZID102 Alarm

Test notes:

1. Good test, heat sensor triggers and CTR notified.
2. During an informal pre-test of the portable heaters output, the plastic case of the smoke/heat detector began to distort while the temperature of the thermocouple was only reading between 115° and 120°F. This heat was applied for about 90 seconds before the case started to melt. The detector is still fully operational.
3. A heat shield fabricated from 1/8" cardboard and aluminum foil will be used to protect the unit during portable heater tests. There is a cut-out for the heat sensor.
4. There is a video record of this test.

3.3 HEAT TEST RECORD

Date: 11-19-91
Time: 2:00 pm

Test Operator: Robert Mugele
Others present to participate in, or witness test:

None

Test Location: Applied Research Associates, Inc. RMD office

1.	Photo-document.	X
2.	Verify Remote and Central Tx/Rx operational.	X
3.	Verify RF link.	X
4.	Turn on video system.	X
5.	Record temperature.	X 81°F (Both)
6.	Apply heat source (portable electric heater).	X 1:46 min:sec
7.	Note temperature at alarm initiation.	X 200°F front 209°F rear
8.	Check Central Tx/Rx for correct message.	X ZID102 Alarm

Test notes:

1. For this test, 2 thermocouples were used to measure temperature at the heat sensor - one attached to the face of the sensor and the other behind the face.
2. AFS works properly, but heat sensor triggering high.
3. There is a video record of this test.
4. One more heat test should be done where position of heater is set so that temperature reads 135°F and wait until alarm.

3.3 HEAT TEST RECORD

Date: 11-26-91
Time: 12:00 pm

Test Operator: Robert Mugele
Others present to participate in, or witness test:

None

Test Location: Applied Research Associates, Inc. RMD office

1.	Photo-document.	None Taken
2.	Verify Remote and Central Tx/Rx operational.	X
3.	Verify RF link.	X
4.	Turn on video system.	X
5.	Record temperature.	X 70°F
6.	Apply heat source.	X
7.	Note temperature at alarm initiation.	X 165°F
8.	Check Central Tx/Rx for correct message.	X

Test notes:

1. The temperature at the heat sensor was held at a minimum of 135°F for 5 minutes without triggering the alarm. More heat was slowly applied and the alarm message was finally sent when the temperature reached 165°F. One minute elapsed while temperature increased from 135°F to 165°F. Strobe base plate deforms slightly (not protected like smoke/heat detector).
2. Video record exists.

3.4 LIVE SMOKE TEST RECORD (DRY RUN)

Date: 11-06-91
Time: 2:00 pm
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 2
Fire/Smoke Source: 30-second smoke generator
AFS height above floor: 3 feet

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify ~~IR~~ (N/A) and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin ~~IR~~ (N/A) and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. This test was also run in an effort to debug all test system components.
2. The AFS system operated correctly. Time duration was measured at 1:29 (min:sec) from smoke output to alarm at CTR.

   Smoke obscuration at the AFS unit was measured to be 3.7% per foot at the time of alarm. Hand-recorded data: V_i=0.212, V_f=0.175.
3. Recorders need to run even longer. Use 10 times initial setting for remaining tests.
4. Video recorded.

3.4 LIVE SMOKE TEST RECORD

Date: 11-12-91
Time: 10:10 am
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 3
Fire/Smoke Source: 30-second smoke generator
AFS height above floor: 3 feet

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify ~~IR~~ (N/A) and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin ~~IR~~ (N/A) and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. Ambient temperature 61°F, clear, calm.
2. Test duration was 119 seconds (AFS @ 3 ft. A.F.L.).
3. Smoke obscuration near the AFS unit was measured at 4.6% per foot at the time of alarm. Hand-recorded data: V_i=0.396, V_f=0.312.
4. Correct alarm message was received at the CTR.
5. Recorder for obscuration at the source did not gather data.
6. Video taped.

3.4 LIVE SMOKE TEST RECORD

Date: 11-12-91
Time: 11:00 am
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 4
Fire/Smoke Source: 30-second smoke generator
AFS height above floor: 3 feet

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify ~~IR~~ (N/A) and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin ~~IR~~ (N/A) and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. Ambient temperature 66°F, clear, calm.
2. Test duration was 124 seconds (AFS @ 3 ft. A.F.L.).
3. Smoke obscuration was measured at 6.5% per foot near the AFS remote unit at the time of alarm. Hand-recorded data: V_i=0.436, V_f=0.312.
4. Good test, correct message at CTR.
5. Video recorded.

3.4 LIVE SMOKE TEST RECORD

Date: 11-12-91
Time: 11:30 am
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 5
Fire/Smoke Source: 30-second smoke generator
AFS height above floor: 6 feet

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify ~~IR~~ (N/A) and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin ~~IR~~ (N/A) and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. Ambient temperature 65°F, clear, calm.
2. Test duration was 121 seconds (AFS @ 6 ft. A.F.L).
3. This was the first test at 6 feet. For the smoke tests, at least two tests were run at each level for comparison of data.
4. Smoke obscuration near the AFS unit was measured at 8.7% at the time of alarm. Manual data: V_i=0.404, V_f=0.256.
5. Good data on all channels.
6. Good test, correct message at CTR.
7. Video taped.

3.4 LIVE SMOKE TEST RECORD

Date: 11-12-91
Time: 12:20 pm
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 6
Fire/Smoke Source: 30-second smoke generator
AFS height above floor: 6 feet

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify ~~IR~~ (N/A) and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin ~~IR~~ (N/A) and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. Ambient temperature 68°F, clear, calm.
2. Test duration was 170 seconds (AFS 6 ft. A.F.L.).
3. Smoke obscuration was measured to be 7.9% per foot at the time of alarm. Manual data: V_i=0.392, V_f=0.260.
4. The smoke detector on the AFS unit took 50 seconds longer to go into alarm than the previous test at the same height. Observing a video record of this test seems to show the smoke detector somewhat slow to respond. When the unit goes into alarm, the strobe cannot be seen through the smoke.
5. Good test. Alarm message was received at the CTR.
6. Video taped.

3.4 LIVE SMOKE TEST RECORD

Date: 11-12-91
Time: 12:50 pm
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 7
Fire/Smoke Source: 30-second smoke generator
AFS height above floor: 0 feet (at floor level)

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify ~~IR~~ (N/A) and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin ~~IR~~ (N/A) and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. Ambient temperature 67°F, clear.
2. This is the first test at floor level.
3. Test duration was 177 seconds.
4. Smoke obscuration at the AFS unit was measured to be 0.7% per foot at the time of alarm. Manual data: V_i=0.614, V_f=0.590.
5. Successful test, correct message received at CTR.
6. Video taped.

3.4 LIVE SMOKE TEST RECORD

Date: 11-12-91
Time: 13:20 pm
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 8
Fire/Smoke Source: 30-second smoke generator
AFS height above floor: 0 feet (at floor level)

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify IR (N/A) and video cameras ready.	X
6.	Verify SCBA (N/A) and fire extinguishers ready.	X
7.	Begin IR (N/A) and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. The timing system triggered approximately 10 seconds too late. Some early time digital data was lost but will not affect the test or its results.
2. Ambient temperature 67°F, clear.
3. Test duration was 223 seconds (AFS @ 0 ft. A.F.L.).
4. Smoke obscuration was measured to be 0.8% per foot near the AFS unit at the time of alarm. Manual data: $V_i=0.624$, $V_f=0.600$.
5. Good test, correct alarm message at CTR.
6. Post test, it was observed that the AFS remote unit was leaking smoke. Inside it was apparent that the smoke was caused by melted/burned battery wiring. It is suspected that the audible horn and strobe draw too much current for prolonged operation. They were both on for approximately 187 seconds during Test 8. The wiring that burned was UL1007 22 gauge, standard jacket.

3.4 LIVE SMOKE TEST RECORD

Date: 11-21-91
Time: 10:00 am
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 9
Fire/Smoke Source: 30-second smoke generator
AFS height above floor: 9.5 feet (ceiling height)

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify ~~IR~~ (N/A) and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin ~~IR~~ (N/A) and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. The damaged battery wiring from Test 8 has been replaced. Wire gauge size and insulation jacket temperature have both been increased. The new wiring is 16 gauge Type E 200°C MIL-W-168780.
2. Ambient temperature was 44°F, clear.
3. This is the first smoke test at ceiling height.
4. Initial trouble getting the Remote Tx/Rx to respond to interrogation (batteries fully charged). Eventually the unit operated properly.
5. Test duration was 39 seconds.
6. Problems with a digital recorder results in no recorded data for the smoke obscuration detector near the AFS unit. However, hand-recorded values indicate smoke obscuration levels of 42% per foot near the AFS at the time of alarm. V_i=0.532, V_f=0.035.
7. Correct alarm message at CTR.
8. Video recorded.

3.4 LIVE SMOKE TEST RECORD

Date: 11-21-91
Time: 10:45 am
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 10
Fire/Smoke Source: 30-second smoke generator
AFS height above floor: 9.5 feet

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify ~~IR~~ (N/A) and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin ~~IR~~ (N/A) and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13	Extinguish fire/evacuate smoke.	X
14	Reset equipment and reconfigure.	X

Test notes:

1. Ambient temperature was 45^{o}F, clear.
2. Test duration was 35 seconds (Test 2 at 9.5 ft. above floor level).
3. Again having difficulties with recorder on SD channel (smoke obscuration near detector). Hand-recorded values indicate 22.5% obscuration per foot at time of alarm. $V_i=0.512$, $V_f=0.143$.
4. Correct message was received at CTR.
5. Video recorded.

3.4 LIVE SMOKE TEST RECORD

Date: 11-21-91
Time: 11:15 am
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 11
Fire/Smoke Source: 30-second smoke generator
AFS height above floor: 9.5 feet

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify ~~IR~~ (N/A) and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin ~~IR~~ (N/A) and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. Ambient temperature was 45°F, clear.
2. Test duration was 53 seconds (Test 3 at 9.5 ft. above floor level).
3. Smoke obscuration was recorded and calculated to be 39% per foot near the AFS unit at the time of alarm. Hand-recorded values: V_i=0.520, V_f=0.043.
4. Correct alarm message was received at CTR.
5. Video taped.

3.4 LIVE FIRE TEST RECORD

Date: 11-21-91
Time: 13:00 pm
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 12 (Fire Test #1)
Fire/Smoke Source: Kerosene/Oil/Fabric Padding
AFS height above floor: 9.5 feet

1.	Photo-document configuration.	X
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify IR and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin IR and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. The AFS system will now be subjected to a live fire consisting of kerosene, oil, and fabric padding. This will produce a sufficient amount of flame and smoke to be detected by the sensors on the AFS unit.
2. Six channels of data will be recorded on these live fire events: time duration, 2 smoke obscuration measurements, and 3 temperature measurements. For temperature data, one thermocouple will be placed near the fire, one near the AFS unit, and one centered in between.
3. Test duration was 13 seconds (AFS @ 9.5 ft. A.F.L.).
4. The graphical data from the smoke obscuration detector near the fire source is of no value. Apparently, the photo cell over-ranges when subjected to a flaming fire at close range.
5. Smoke obscuration near the AFS unit was measured at 2.6% per foot at the time of alarm.

6. Temperatures near the source were 149°F at the time of alarm, with a brief maximum of 441°F about midway through the test.
7. No data was captured on the middle temperature gage due to some technical difficulties.
8. Temperature near the AFS unit was 82°F at the time of alarm.
9. Ambient conditions prior to the test were 42°F, clear.
10. Overall, the test was successful. The AFS system seemed to respond much quicker to a real fire situation versus the smoke generators or the heat-only testing. The correct message was received at the CTR.
11. It is believed that the smoke alarm triggered the alarm judging by the temperature at the AFS.
12. Video taped.
13. IR photography was attempted with the camera looking in the direction of the AFS unit.
14. Hand-recorded data: SD12, V_i=0.499, V_f=0.438.

3.4 LIVE FIRE TEST RECORD

Date: 11-21-91
Time: 13:55 pm
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 13 (Fire Test #2)
Fire/Smoke Source: Kerosene/Oil/Fabric Padding
AFS height above floor: 6 feet

1. Photo-document configuration. None
   Identical to Test #12 (Live Fire #1) except for new location (height) of AFS unit.
2. Verify all batteries charged and equipment operational. X
3. Verify all AC equipment operational. X
4. Verify RF link. X
5. Verify IR and video cameras ready. X
6. Verify ~~SCBA~~ (N/A) and fire extinguishers ready. X
7. Begin IR and video cameras. X
8. Document initial instrumentation data parameters. X
9. Ignite fuel source. X
10. Trigger data recorders. X
11. Wait for alarm. X
12. Shut off recorders. X
13. Extinguish fire/evacuate smoke. X
14. Reset equipment and reconfigure. X

Test notes:

1. Ambient conditions were 42°F, clear.
2. AFS unit 6 feet above floor level.
3. Test duration was 23 seconds.
4. Smoke obscuration near source: no data – photo cell overranges. Smoke obscuration near AFS unit: hand-recorded to be 1.5% per foot at the time of alarm, V_i=0.556, V_f=0.516. The graphical data indicates 2.9% per foot.
5. Temperature near the source reached 98°F.
6. Temperature near the AFS unit reached 78°F.
7. Good test, correct message at CTR.
8. Video recorder panned over to fire.
9. IR photography attempted.

3.4 LIVE FIRE TEST RECORD

Date: 11-21-91
Time: 14:22 pm
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 14 (Fire Test #3)
Fire/Smoke Source: Kerosene/Oil/Fabric Padding
AFS height above floor: 3 feet

1.	Photo-document configuration. Identical to Test #12 (Live Fire #1) except for new location (height) of AFS unit.	None
2.	Verify all batteries charged and equipment operational.	X
3.	Verify all AC equipment operational.	X
4.	Verify RF link.	X
5.	Verify IR and video cameras ready.	X
6.	Verify ~~SCBA~~ (N/A) and fire extinguishers ready.	X
7.	Begin IR and video cameras.	X
8.	Document initial instrumentation data parameters.	X
9.	Ignite fuel source.	X
10.	Trigger data recorders.	X
11.	Wait for alarm.	X
12.	Shut off recorders.	X
13.	Extinguish fire/evacuate smoke.	X
14.	Reset equipment and reconfigure.	X

Test notes:

1. Ambient conditions 42°F, clear skies.
2. AFS unit 3 feet above floor level.
3. Test duration was 72 seconds.
4. No data on channels SS and TM (smoke near source and temperature middle).
5. Smoke obscuration was measured at between 3.0 and 3.8% per foot (notes vs. graphical) at the time of alarm. Hand-recorded values: V_i=0.528, V_f=0.453.
6. Temperature of the environment near the fire was 172°F.
7. Temperature of the environment near the AFS unit reached 63°F.
8. The correct message was received at the CTR.
9. Video taped.
10. IR photography attempted.

3.4 LIVE FIRE TEST RECORD

Date: 11-21-91
Time: 14:45 pm
Test Operator: Robert Mugele
Others present to participate in, or witness test:
Bob Guice
Test Location: Applied Research Associates, Inc. - Test Site
Live Test Number: 15 (Fire Test #4)
Fire/Smoke Source: Kerosene/Oil/Fabric Padding
AFS height above floor: 0 feet

1. Photo-document configuration. None
   Identical to Test #12 (Live Fire #1) except for new location (height) of AFS unit.
2. Verify all batteries charged and equipment operational. X
3. Verify all AC equipment operational. X
4. Verify RF link. X
5. Verify IR and video cameras ready. X
6. Verify ~~SCBA~~ (N/A) and fire extinguishers ready. X
7. Begin IR and video cameras. X
8. Document initial instrumentation data parameters. X
9. Ignite fuel source. X
10. Trigger data recorders. X
11. Wait for alarm. X
12. Shut off recorders. X
13. Extinguish fire/evacuate smoke. X
14. Reset equipment and reconfigure. X

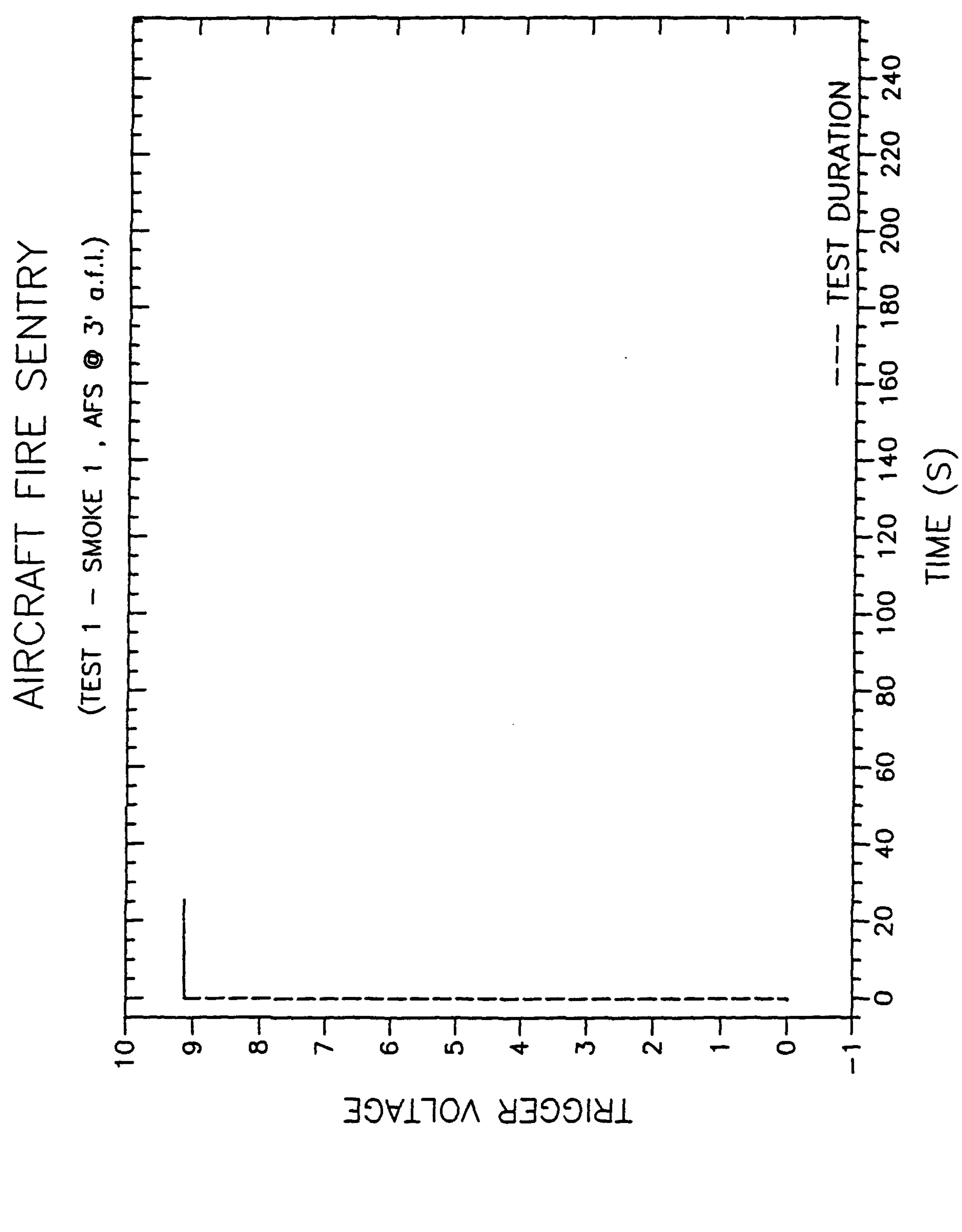
Test notes:

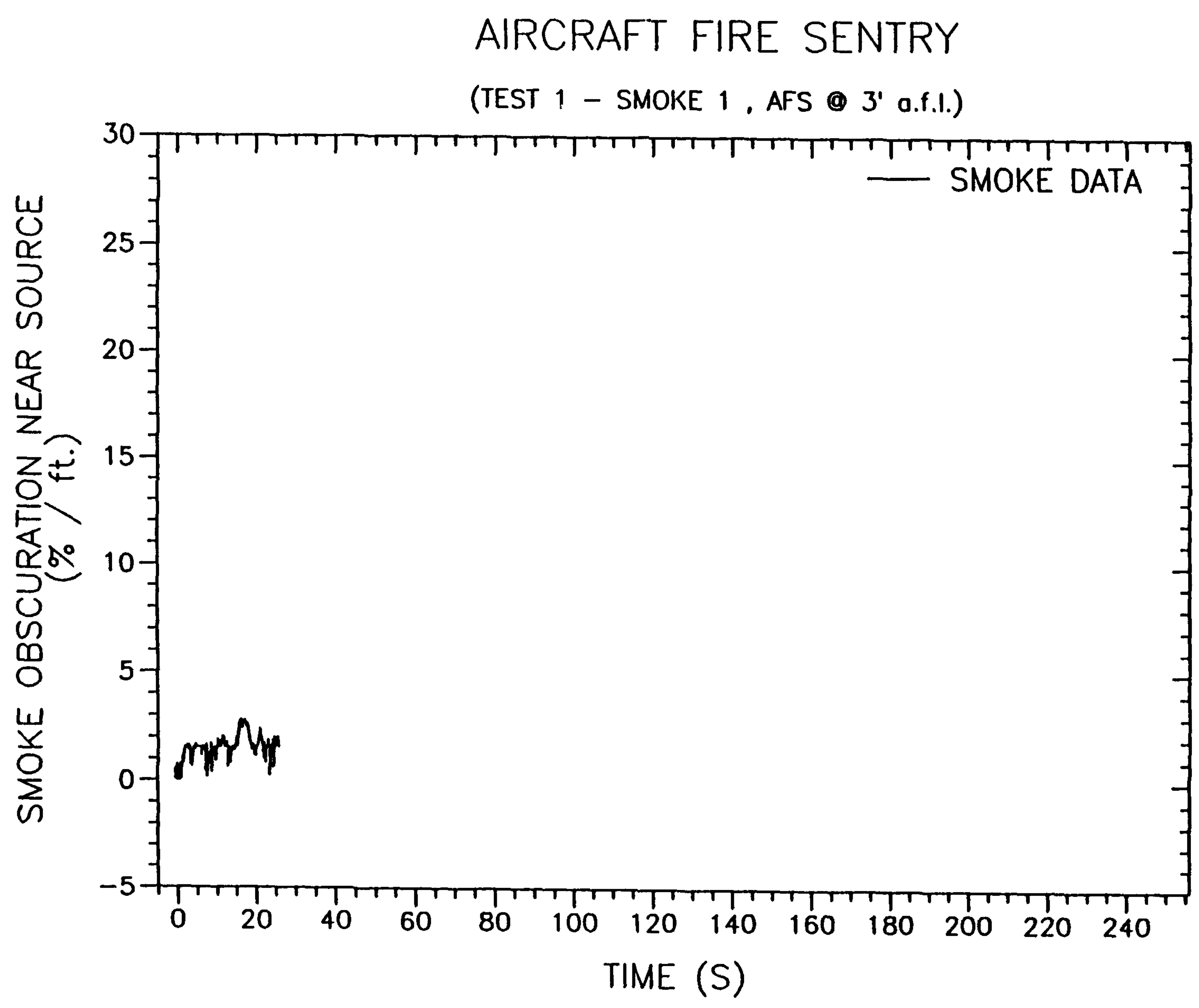
1. Ambient conditions were 42°F, clear.
2. AFS unit sitting at floor level.
3. Test duration was 137 seconds.
4. No data on channels SS and TM.
5. Smoke obscuration at the AFS unit was measured at 6.5% per foot and 6.1% per foot at the time of alarm (notes vs. graphical). Notes: V_i=0.664, V_f=0.475.
6. The temperature near the fire reached 193°F.
7. The temperatu near the AFS unit reached 57°F.
8. The correct message was received at the CTR.
9. Video taped.
10. IR photography attempted.

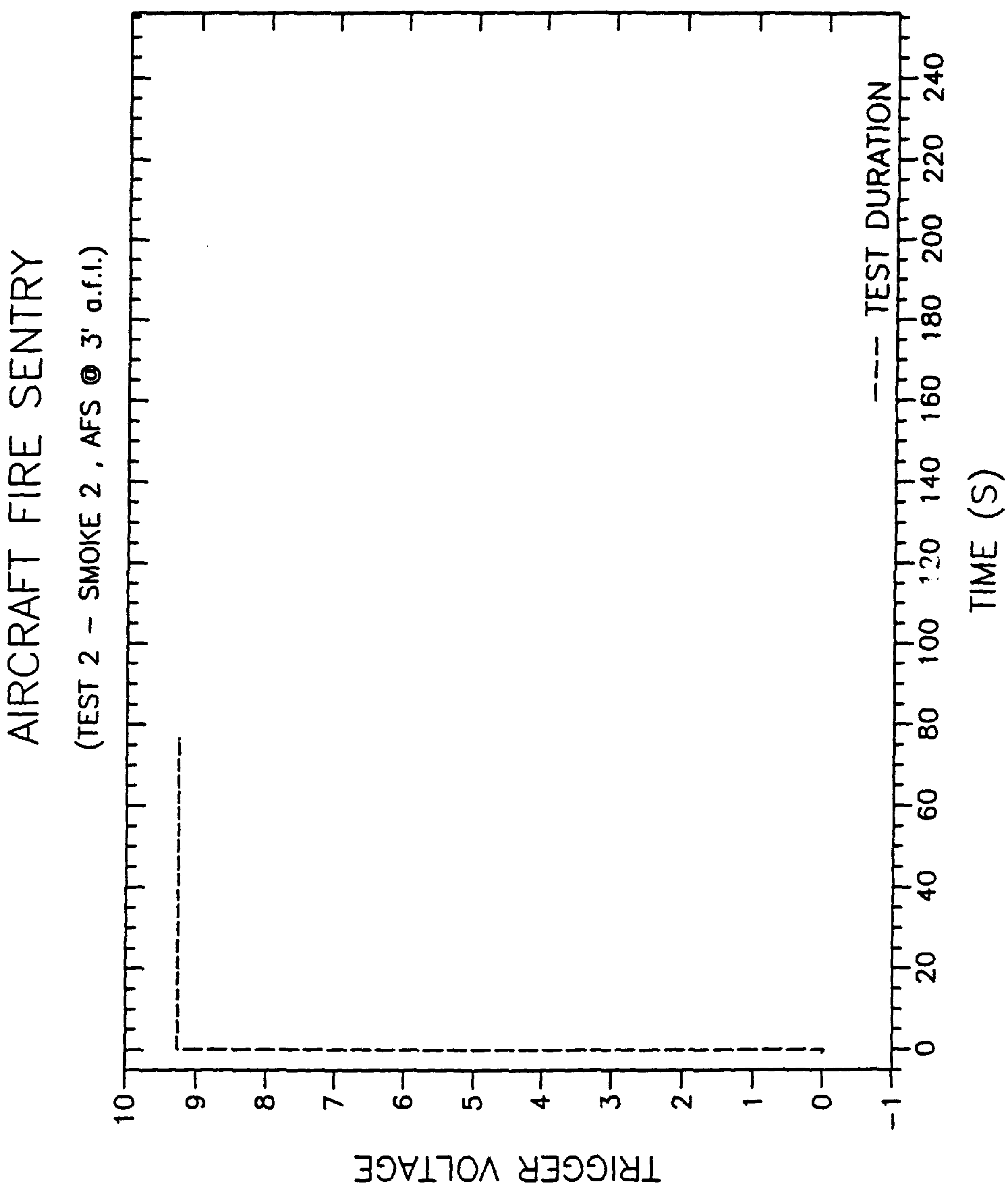
APPENDIX B

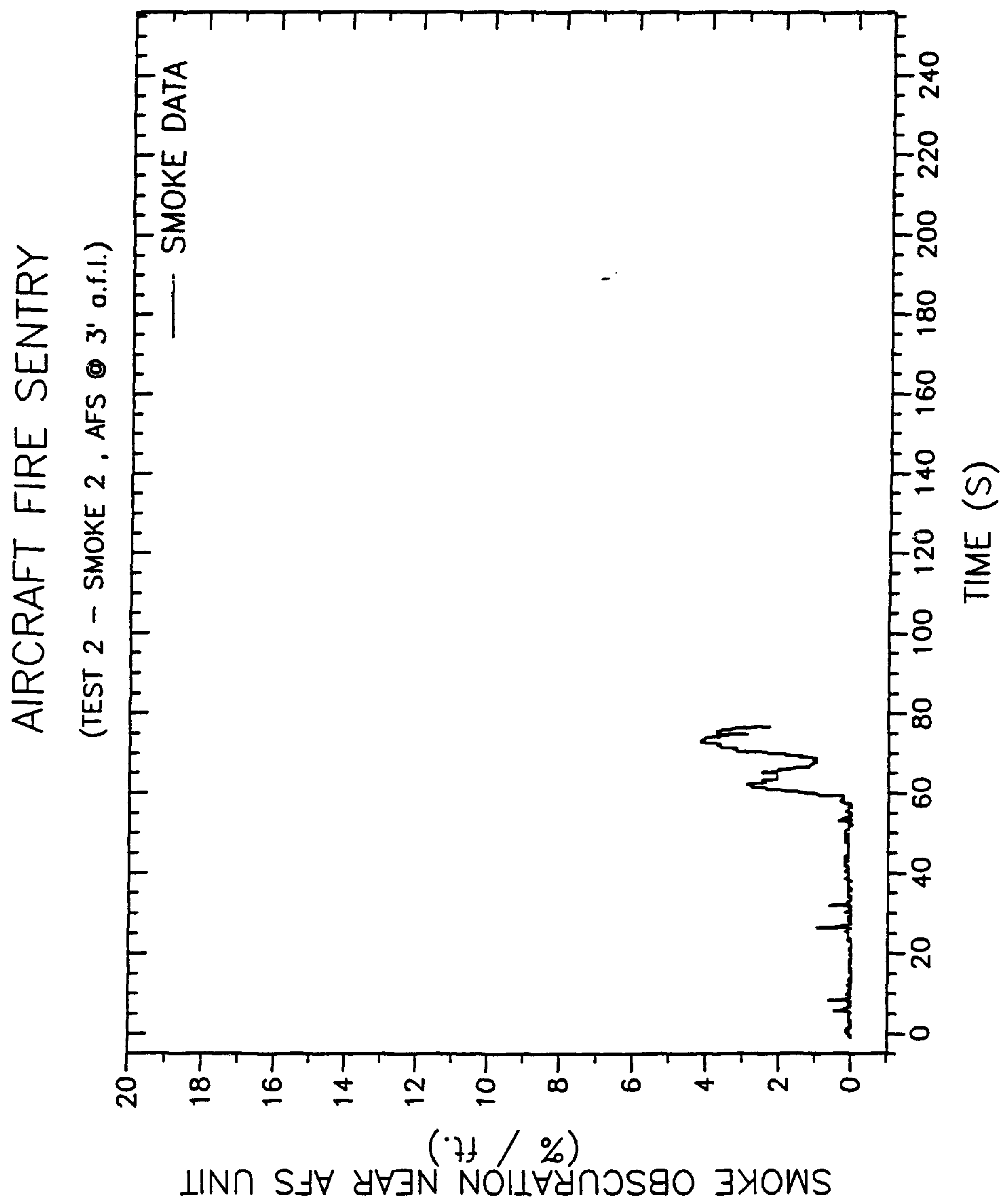
ANNEX C

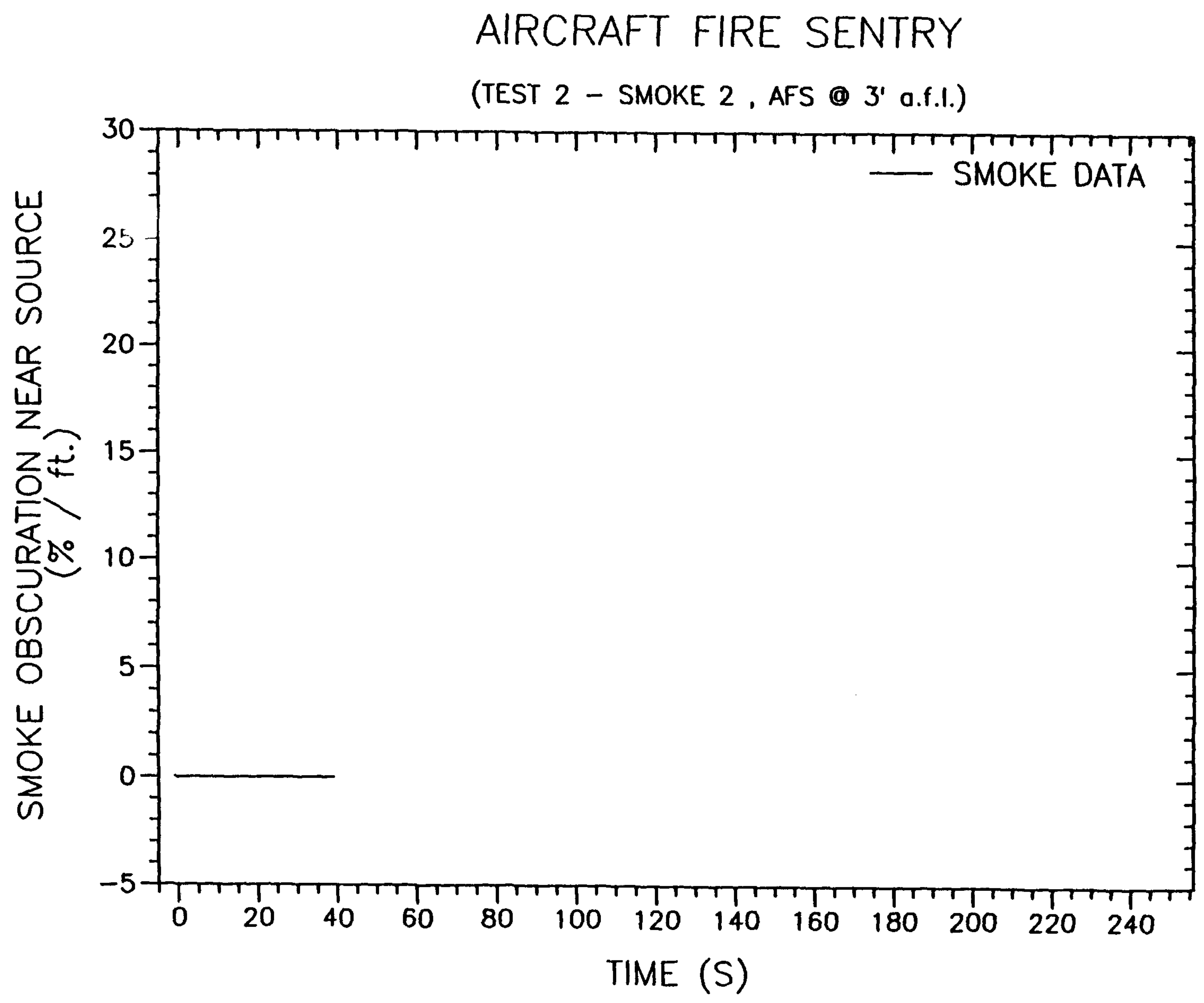
This annex is a collection of all of the digitally recorded data gathered during the Task 2 test series. The types of plots include test duration, shown as trigger voltage versus time, smoke obscuration versus time, and temperature increase versus time. Graphical data is incomplete for the first two tests due to adjustment of recording software.


AIRCRAFT FIRE SENTRY
(TEST 1 - SMOKE 1 , AFS @ 3' a.f.l.)
--- TEST DURATION
TRIGGER VOLTAGE
TIME (S)
-1
0
1
2
3
4
5
6
7
8
9
10
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
(TEST 1 - SMOKE 1 , AFS @ 3' a.f.l.)
SMOKE DATA
SMOKE OBSCURATION NEAR SOURCE (% / ft.)
TIME (S)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
140
160
180
200
220
240

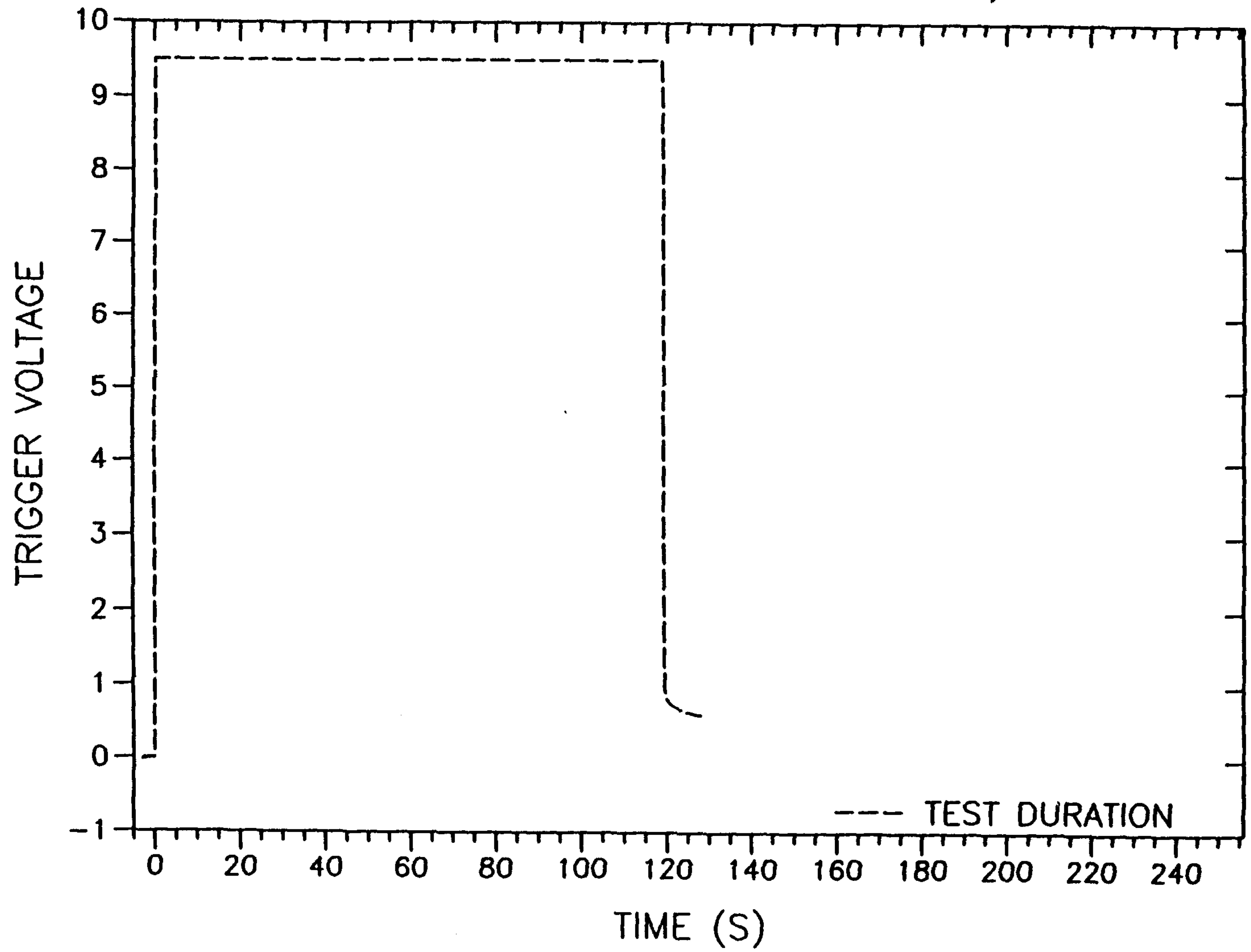

AIRCRAFT FIRE SENTRY
(TEST 2 - SMOKE 2 , AFS @ 3' a.f.l.)
TRIGGER VOLTAGE
TIME (S)
--- TEST DURATION
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
160
180
200
220
240

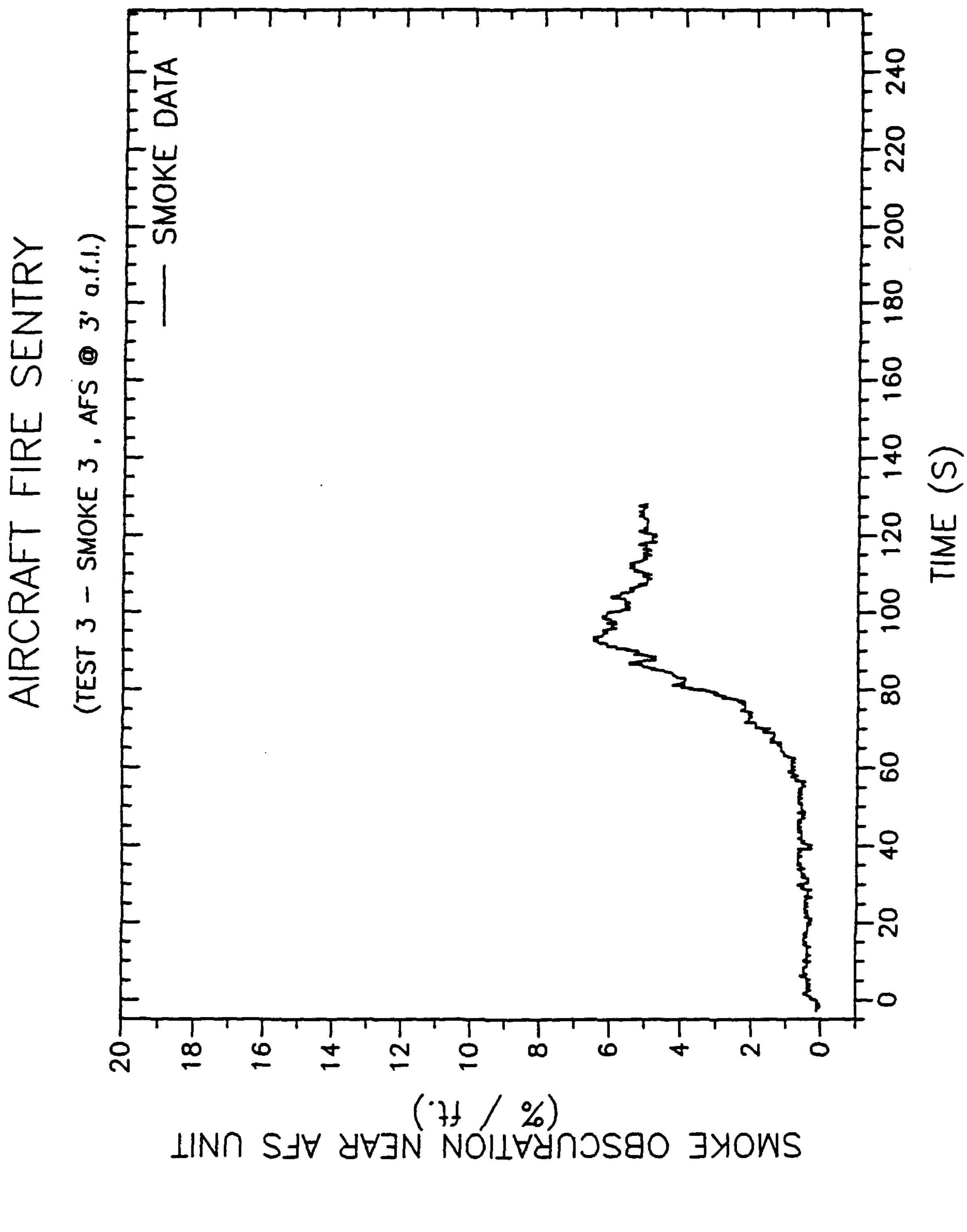

AIRCRAFT FIRE SENTRY
(TEST 2 - SMOKE 2 , AFS @ 3' a.f.l.)
SMOKE DATA
TIME (S)
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
2
4
6
8
10
12
14
16
18
20

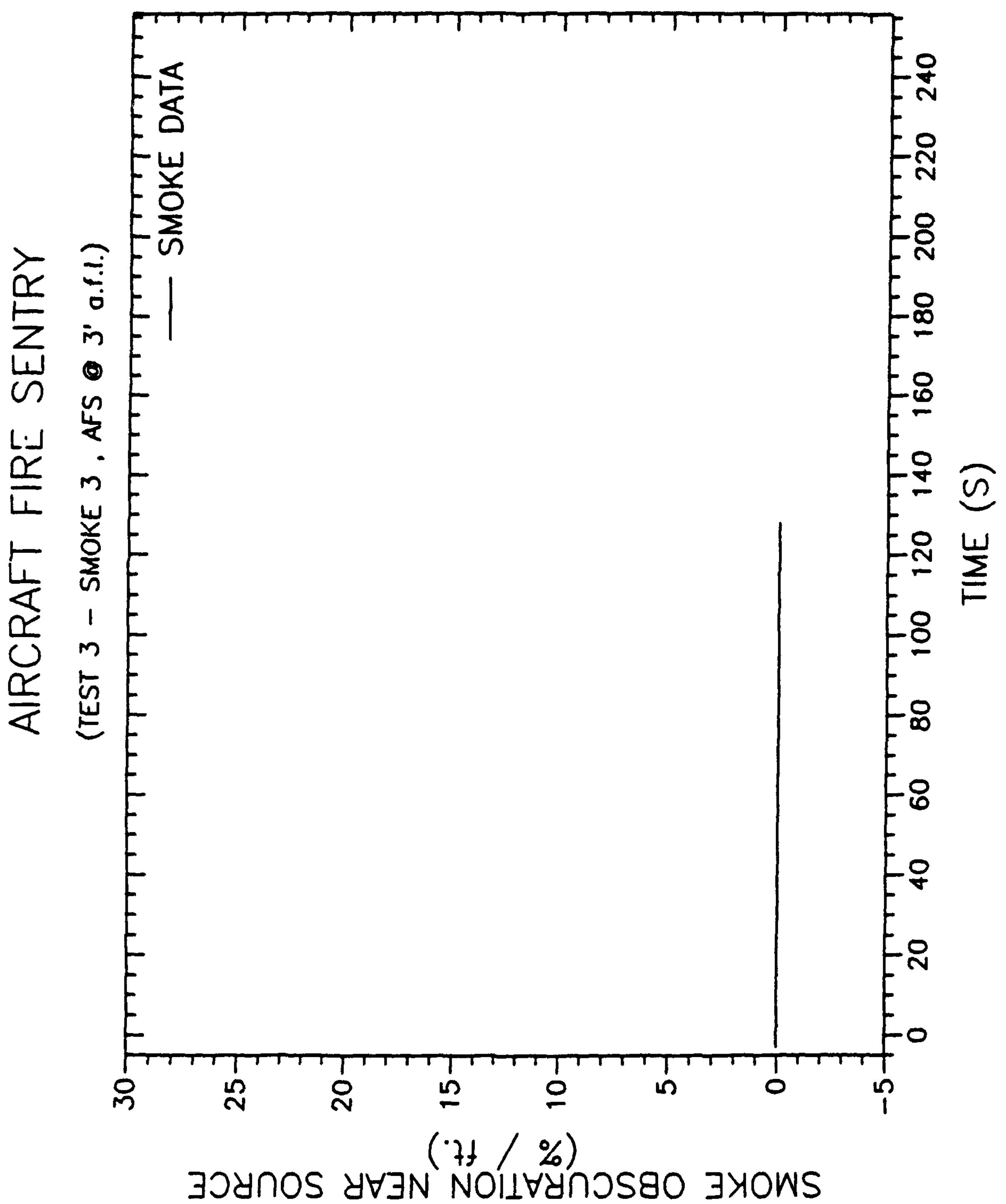

AIRCRAFT FIRE SENTRY
(TEST 2 - SMOKE 2 , AFS @ 3' a.f.l.)
SMOKE DATA
SMOKE OBSCURATION NEAR SOURCE (% / ft.)
TIME (S)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
140
160
180
200
220
240

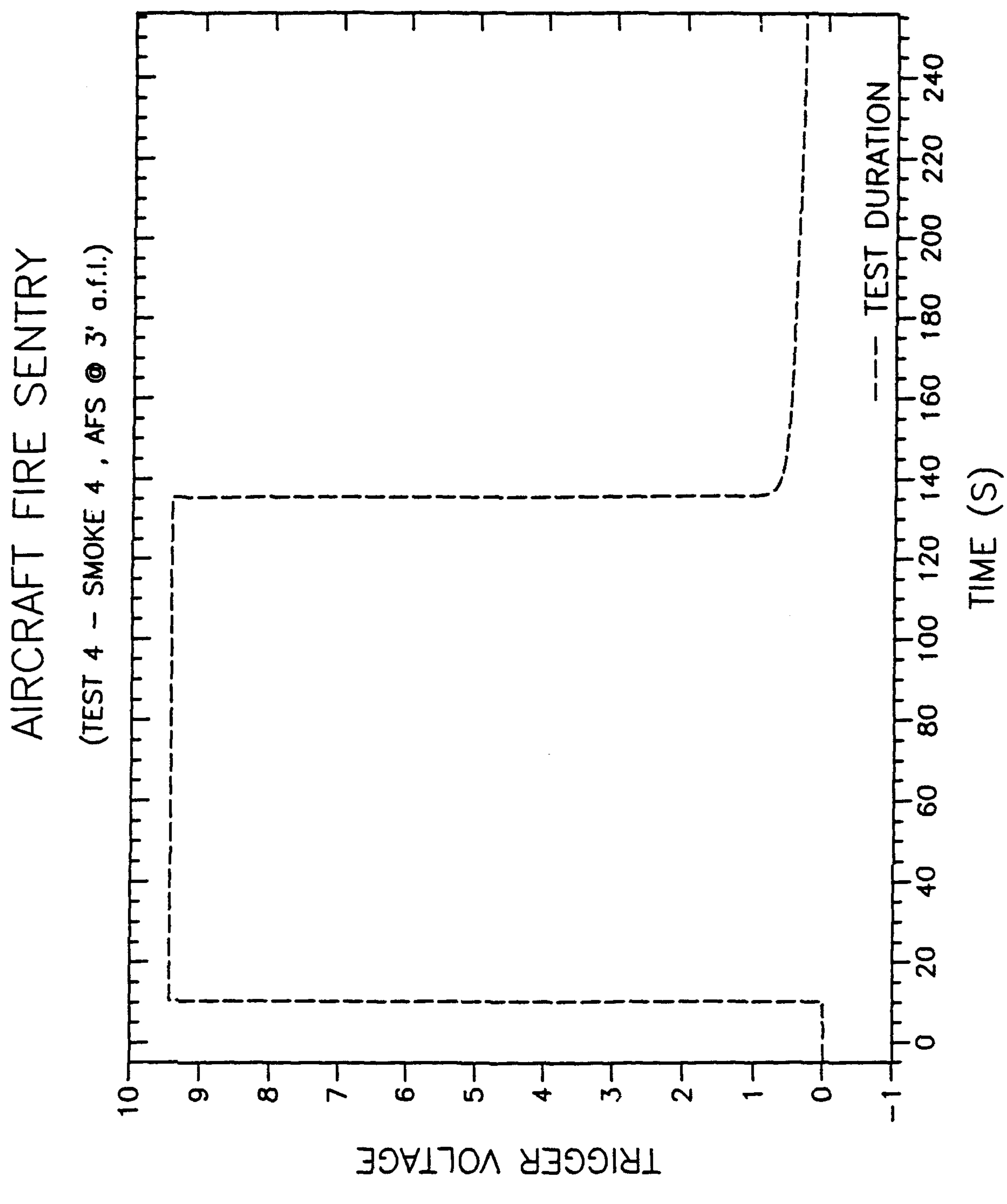
AIRCRAFT FIRE SENTRY

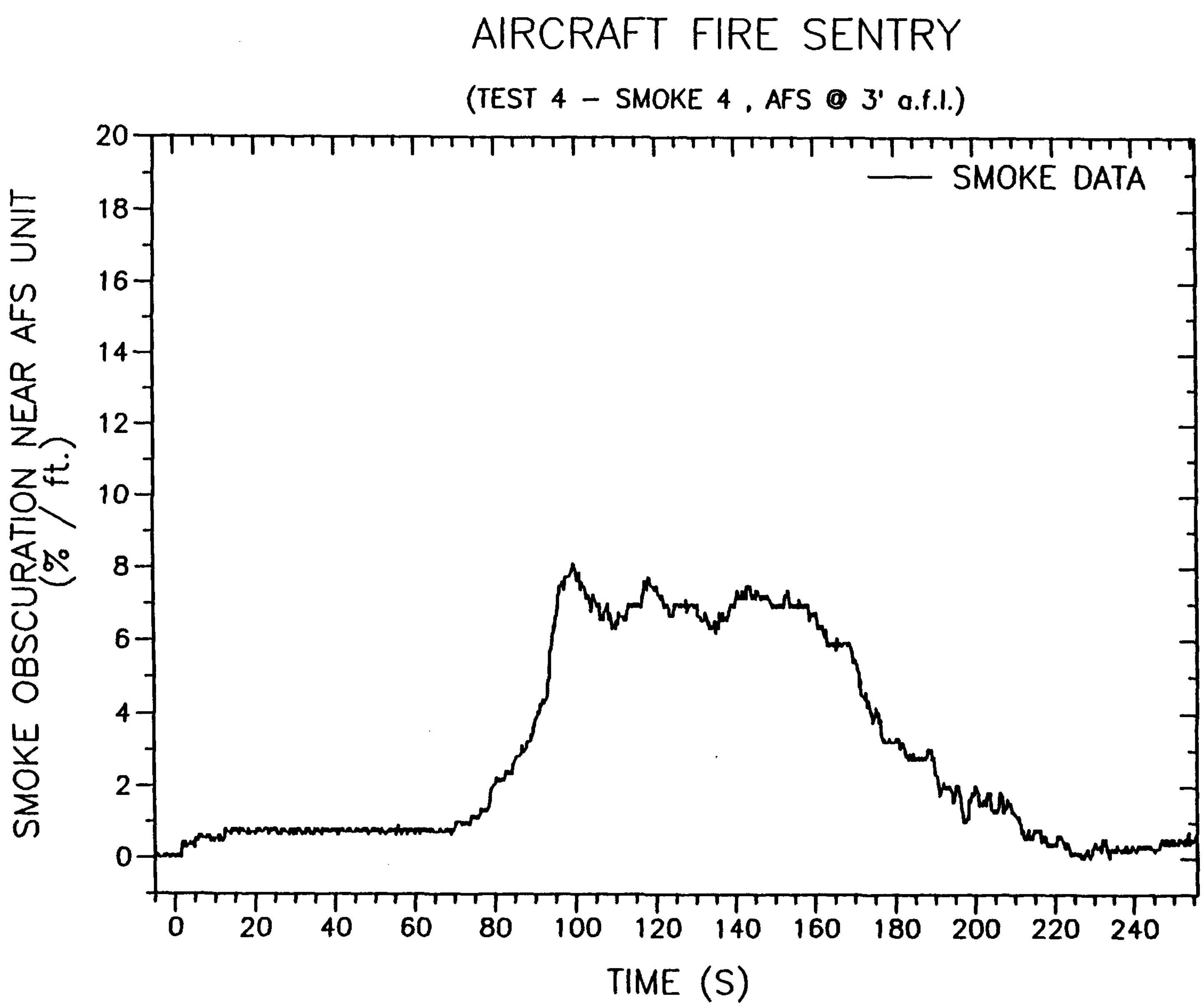
(TEST 3 – SMOKE 3 , AFS @ 3' a.f.l.)




AIRCRAFT FIRE SENTRY
(TEST 3 - SMOKE 3 , AFS @ 3' a.f.l.)
— SMOKE DATA
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
TIME (S)
0
2
4
6
8
10
12
14
16
18
20
40
60
80
100
120
140
160
180
200
220
240

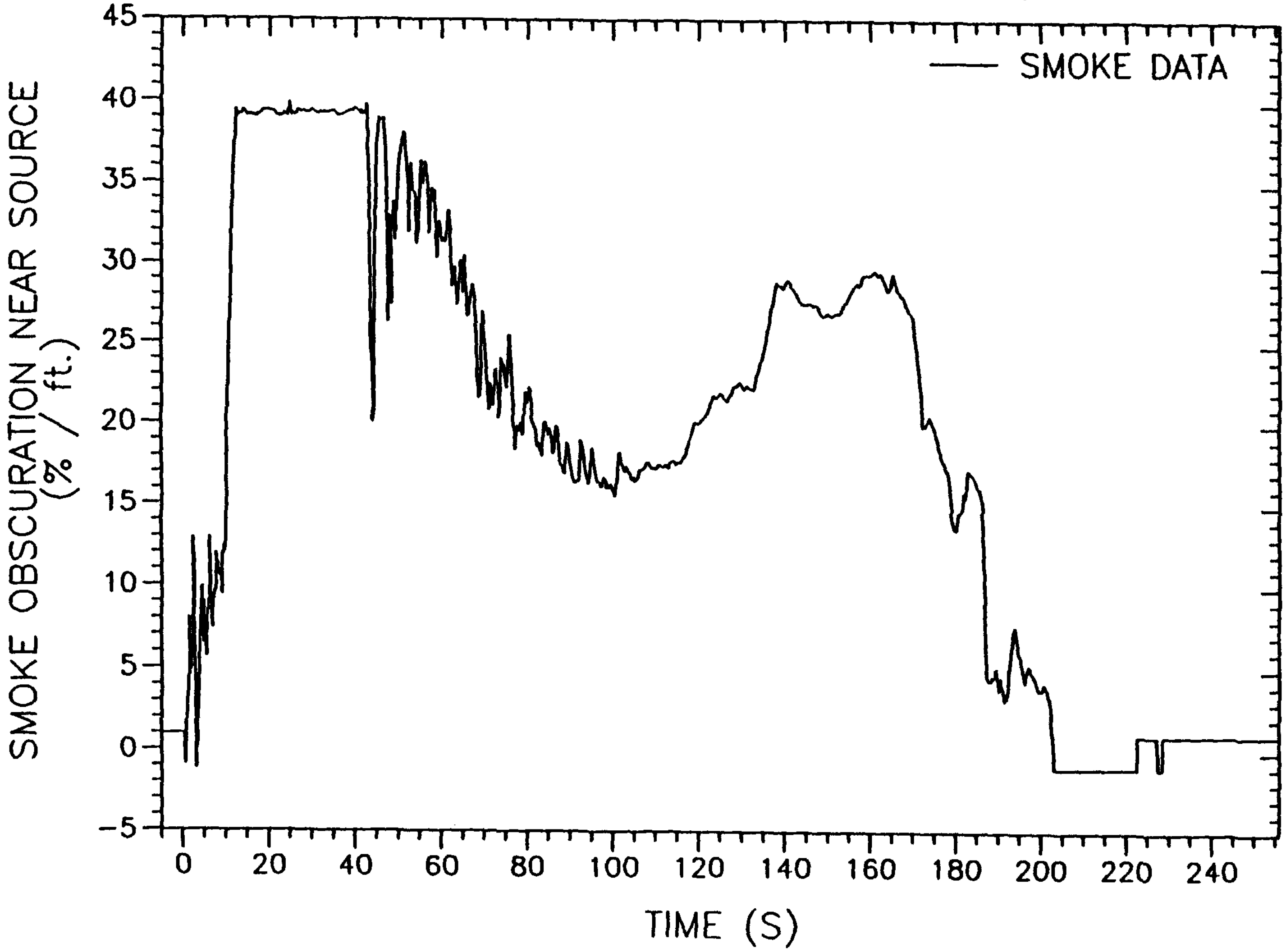

AIRCRAFT FIRE SENTRY
(TEST 3 - SMOKE 3 , AFS @ 3' a.f.l.)
SMOKE DATA
TIME (S)
SMOKE OBSCURATION NEAR SOURCE (% / ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
-5
0
5
10
15
20
25
30

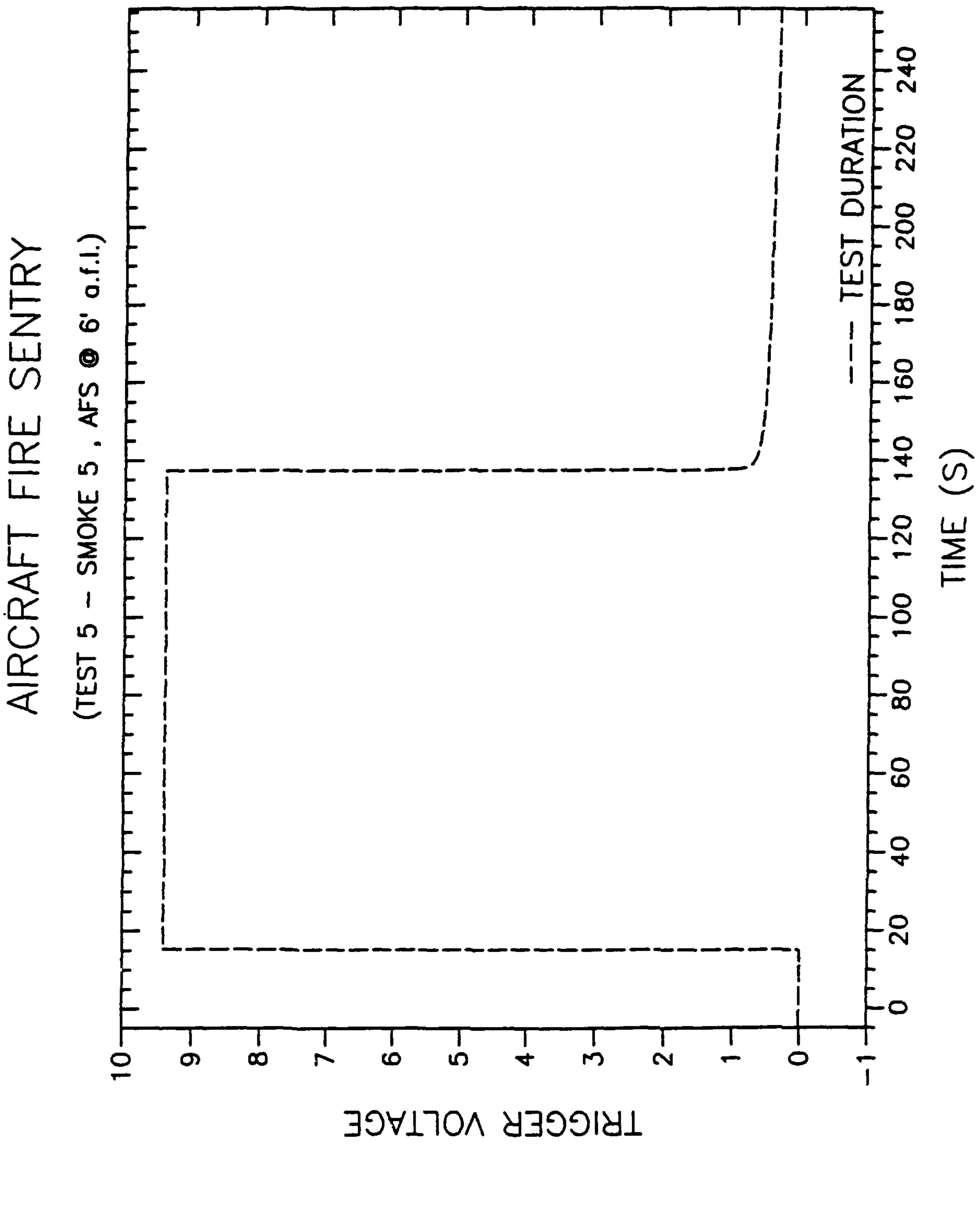

AIRCRAFT FIRE SENTRY
(TEST 4 - SMOKE 4 , AFS @ 3' a.f.l.)
TRIGGER VOLTAGE
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)
--- TEST DURATION

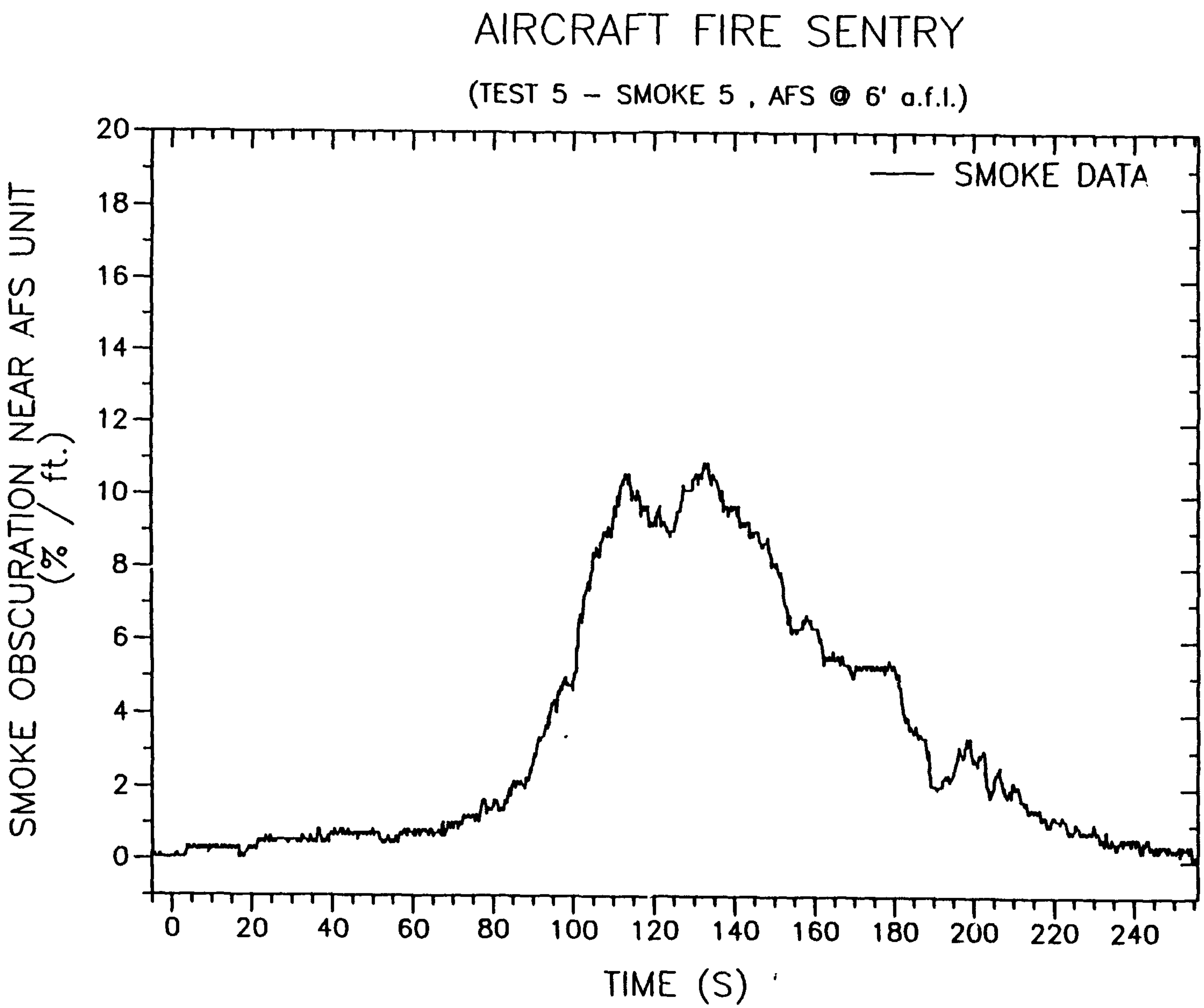

AIRCRAFT FIRE SENTRY
(TEST 4 – SMOKE 4 , AFS @ 3' a.f.l.)
SMOKE DATA
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240
2
4
6
8
10
12
14
16
18

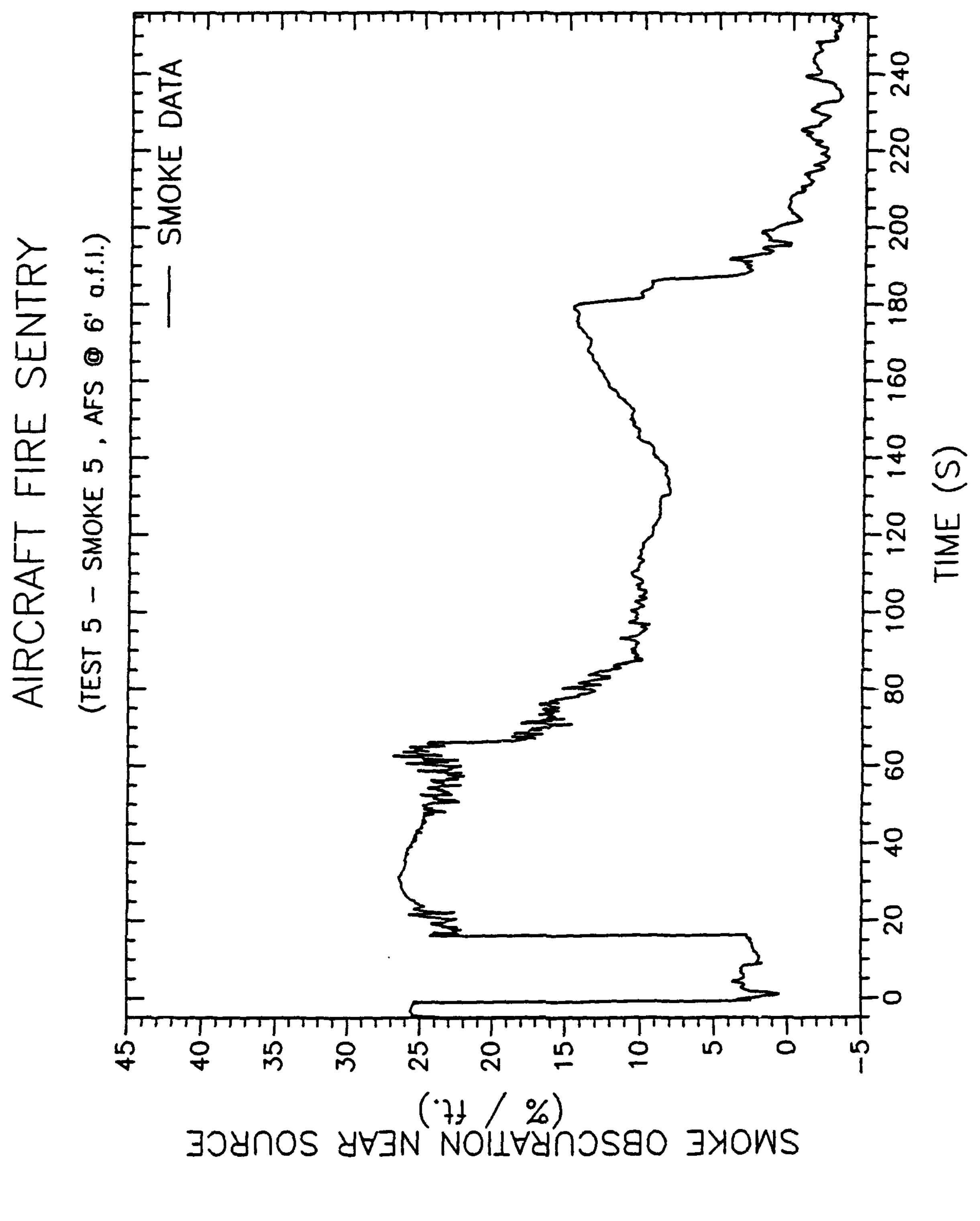
AIRCRAFT FIRE SENTRY

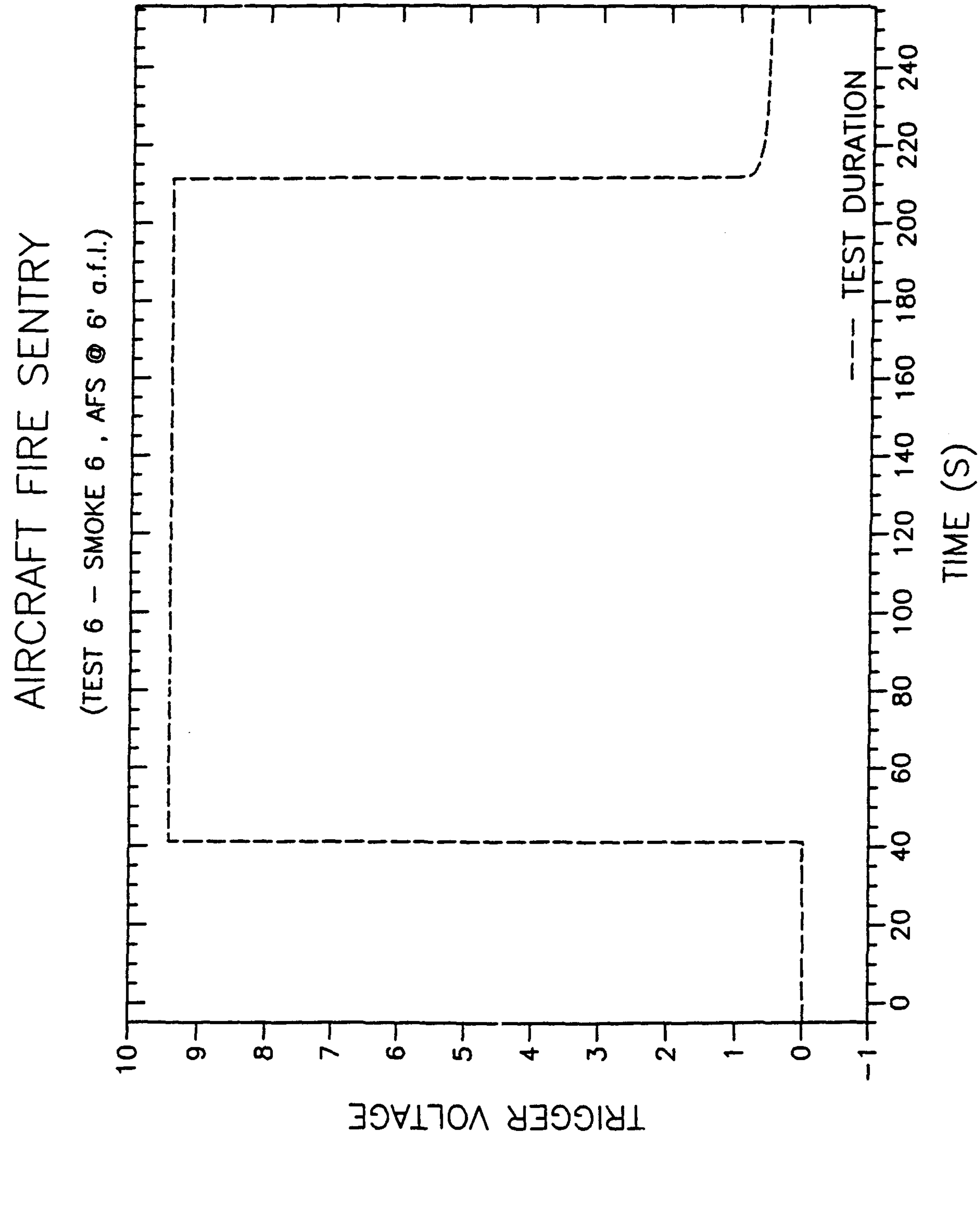
(TEST 4 - SMOKE 4 , AFS @ 3' a.f.l.)

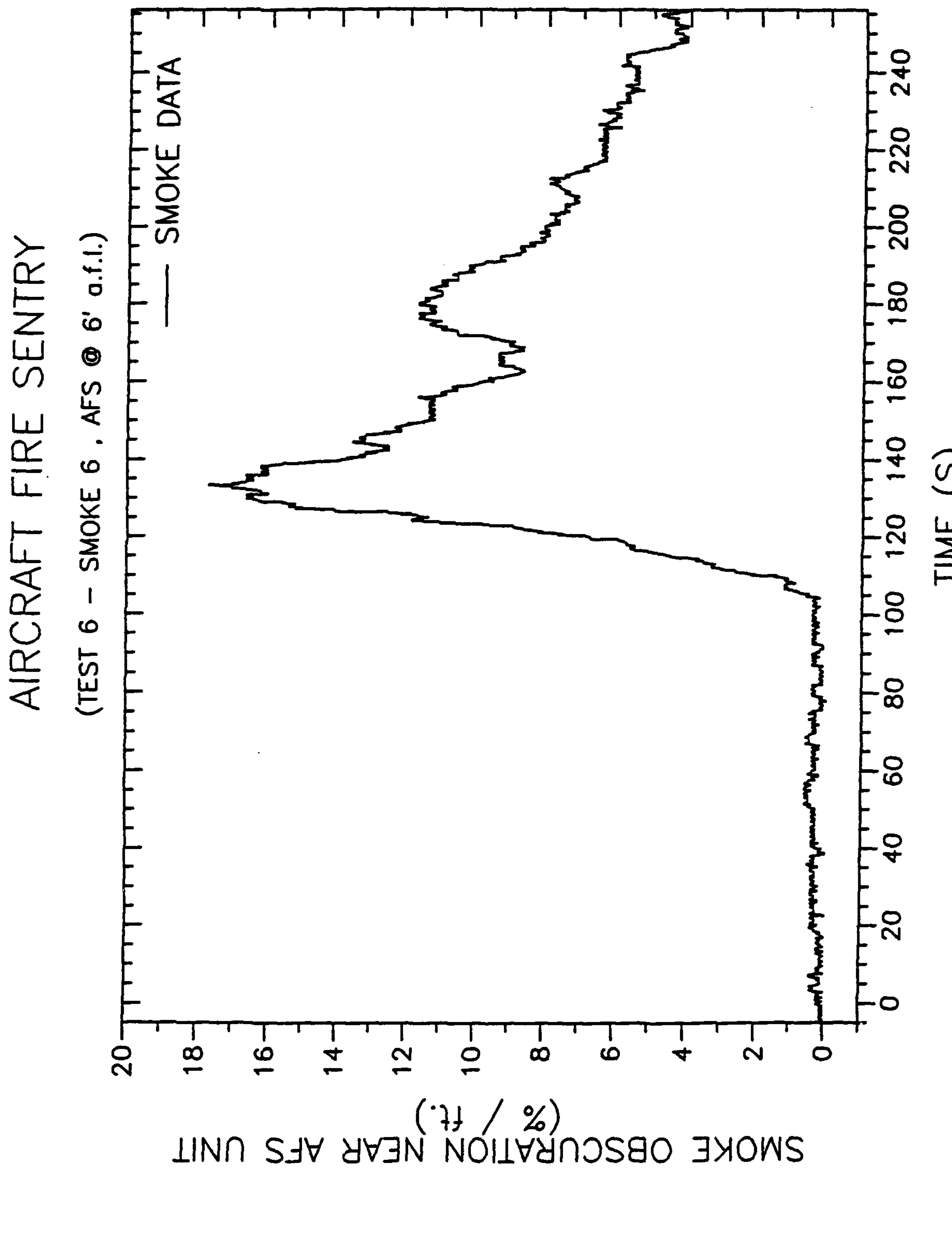


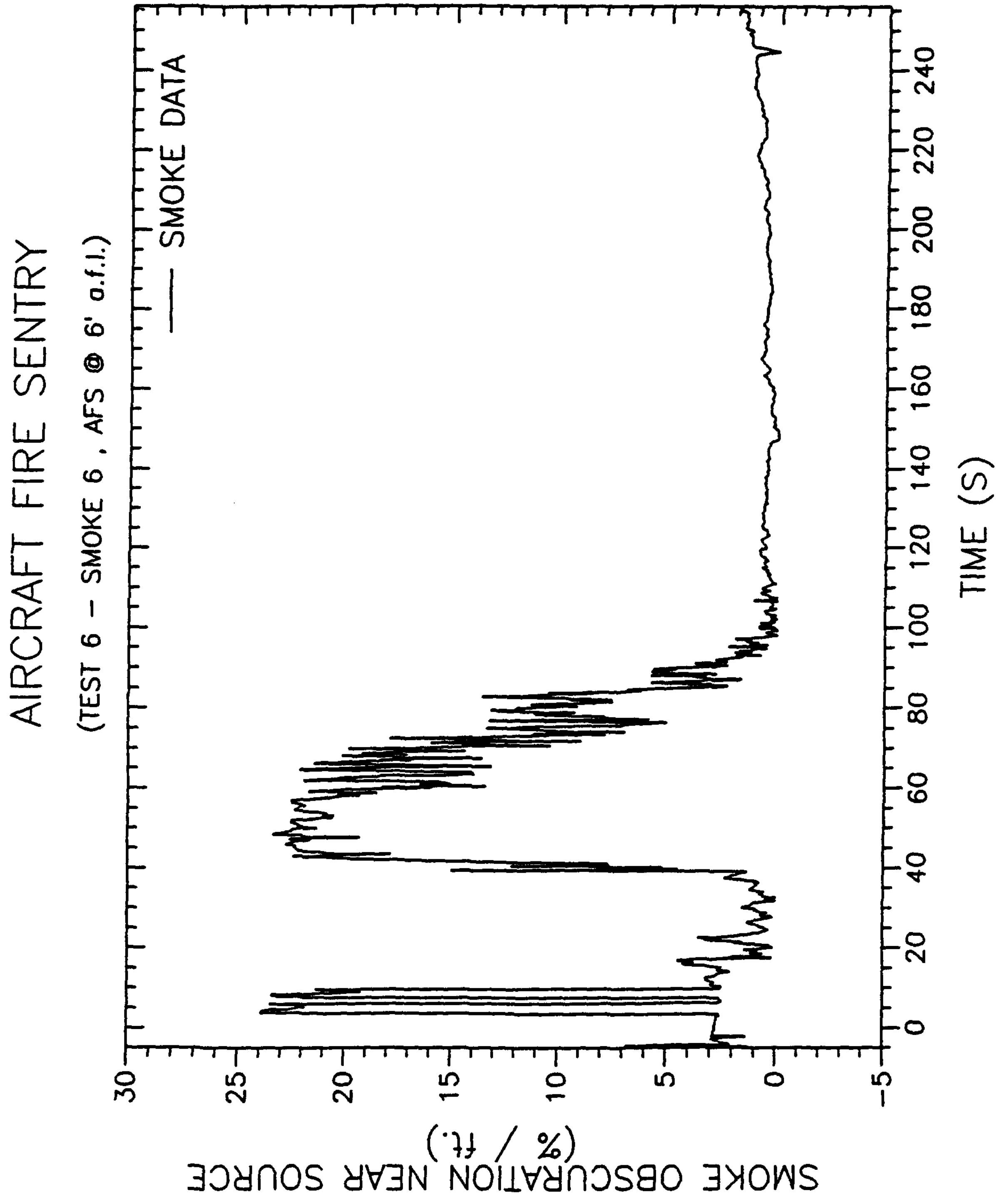

AIRCRAFT FIRE SENTRY
(TEST 5 -- SMOKE 5 , AFS @ 6' a.f.l.)
TRIGGER VOLTAGE
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)
--- TEST DURATION

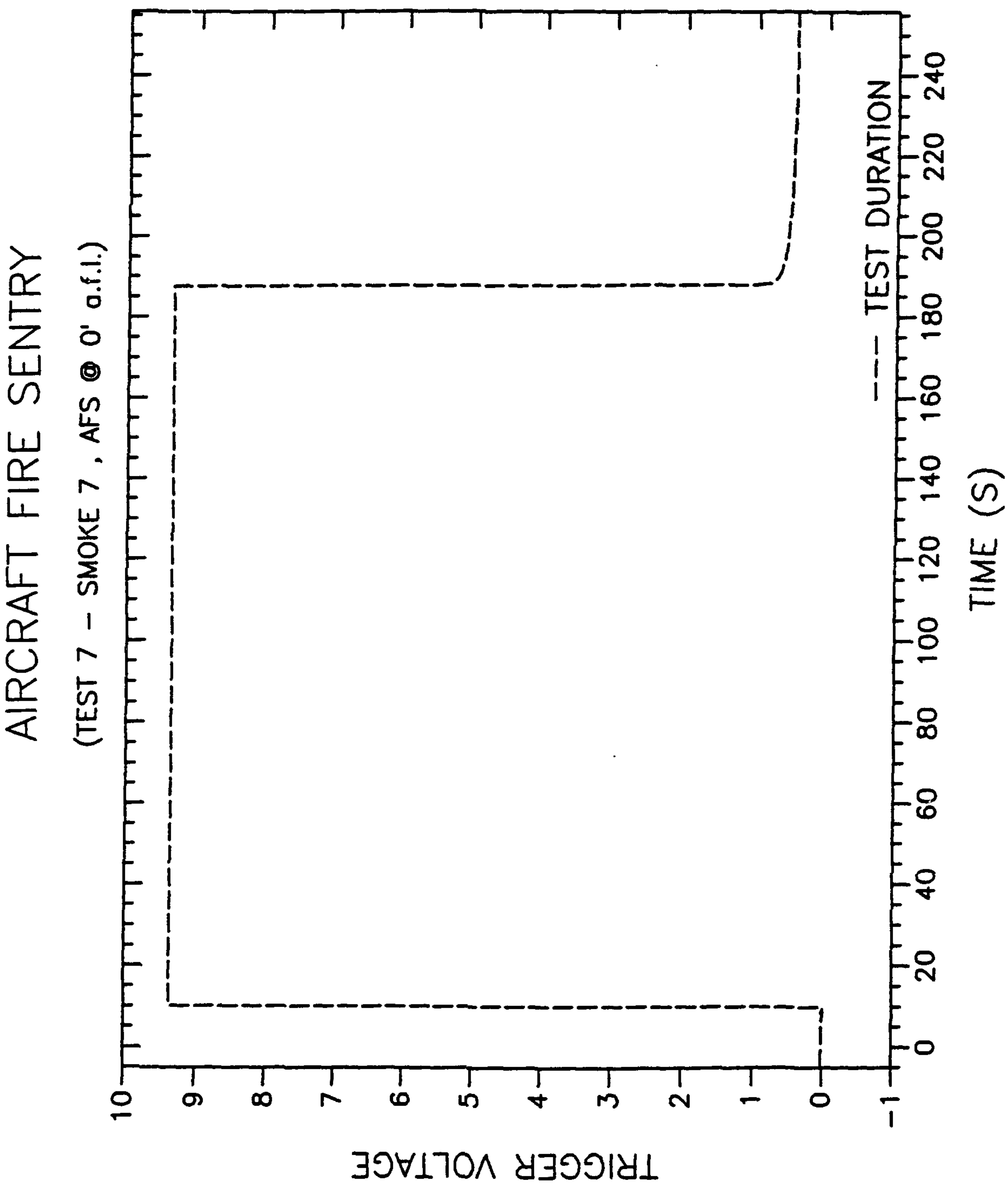

AIRCRAFT FIRE SENTRY
(TEST 5 – SMOKE 5 , AFS @ 6' a.f.l.)
SMOKE DATA
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
TIME (S)
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
(TEST 5 – SMOKE 5 , AFS @ 6' a.f.l.)
—— SMOKE DATA
SMOKE OBSCURATION NEAR SOURCE (% / ft.)
TIME (S)
45
40
35
30
25
20
15
10
5
0
–5
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
(TEST 6 – SMOKE 6 , AFS @ 6' a.f.l.)
TRIGGER VOLTAGE
TIME (S)
– – – TEST DURATION
10
9
8
7
6
5
4
3
2
1
0
–1
0
20
40
60
80
100
120
140
160
180
200
220
240

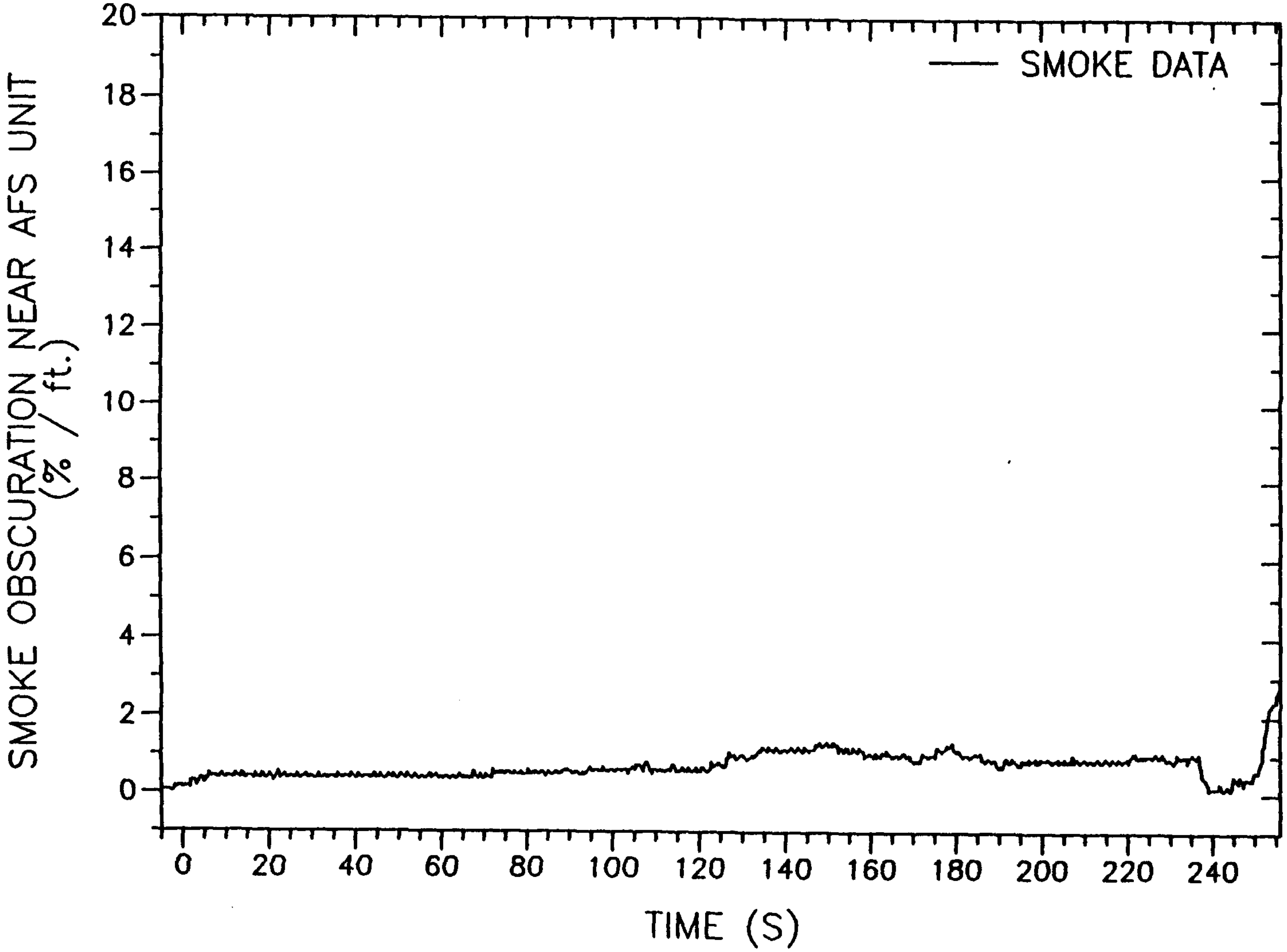

AIRCRAFT FIRE SENTRY
(TEST 6 – SMOKE 6 , AFS @ 6' a.f.l.)
— SMOKE DATA
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
TIME (S)
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
(TEST 6 - SMOKE 6 , AFS @ 6' a.f.l.)
SMOKE DATA
SMOKE OBSCURATION NEAR SOURCE (% / ft.)
TIME (S)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
(TEST 7 – SMOKE 7 , AFS @ 0' a.f.l.)
TRIGGER VOLTAGE
TIME (S)
TEST DURATION
10
9
8
7
6
5
4
3
2
1
0
–1
0
20
40
60
80
100
120
140
160
180
200
220
240

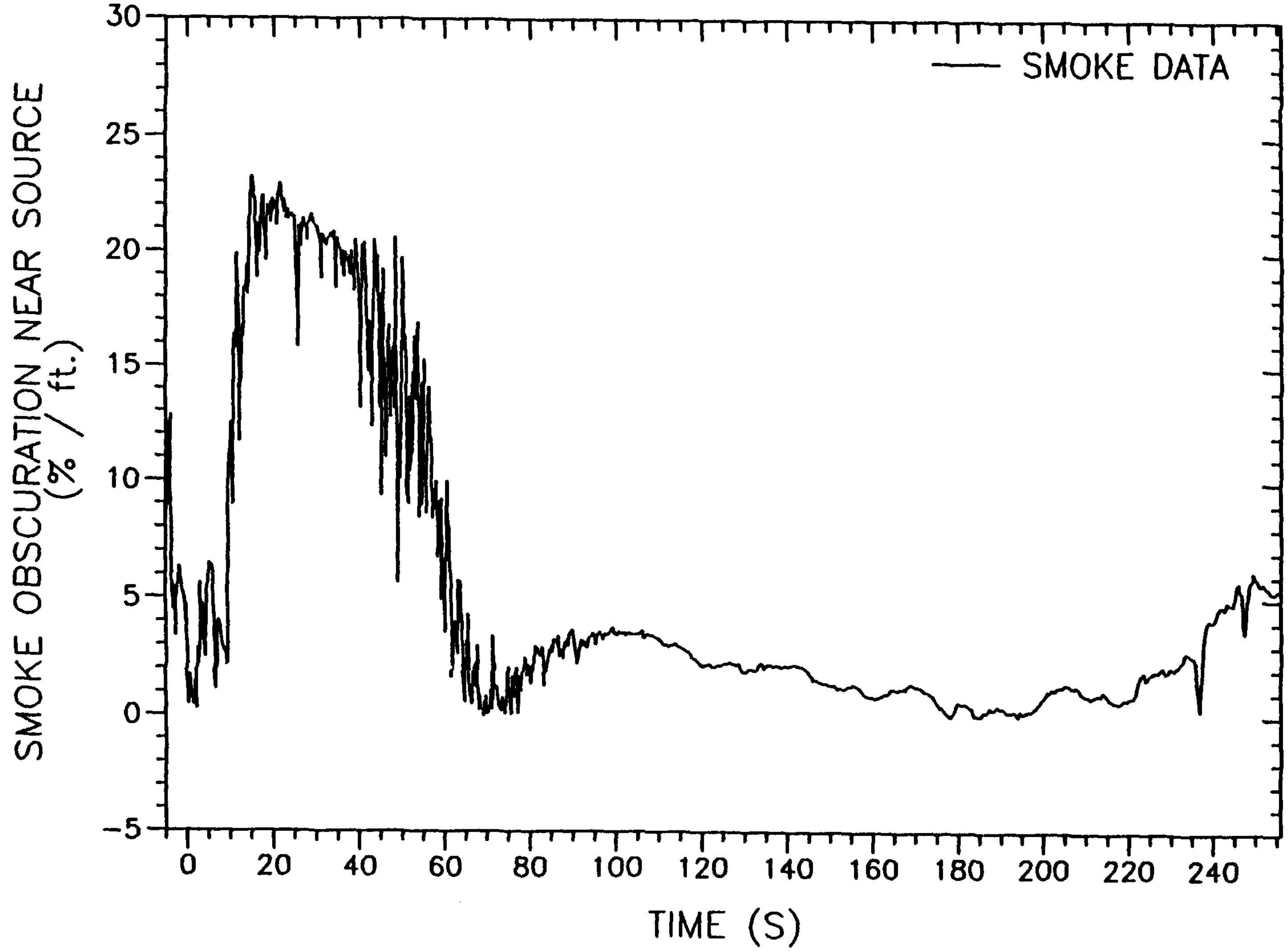
AIRCRAFT FIRE SENTRY

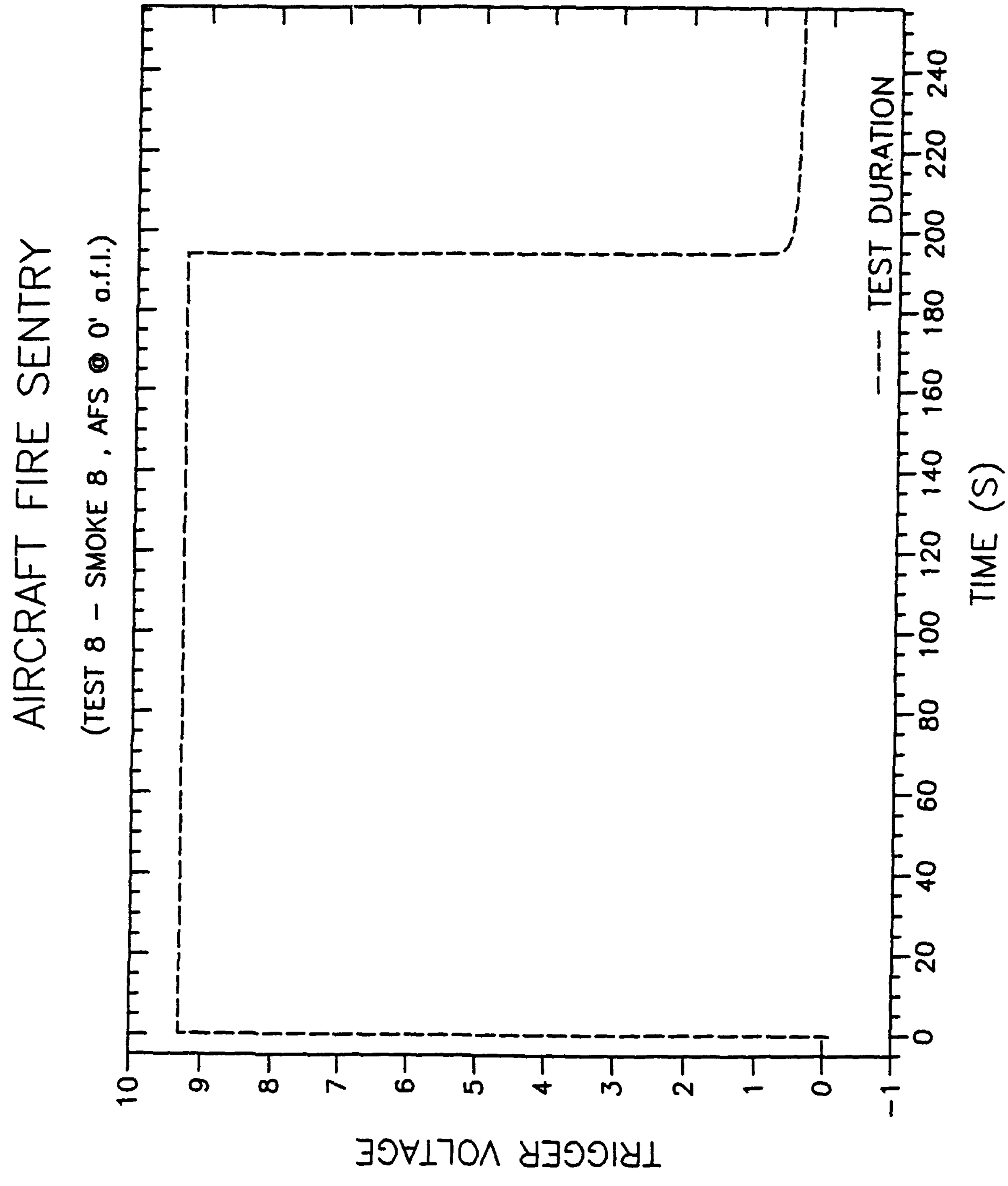
(TEST 7 – SMOKE 7 , AFS @ 0' a.f.l.)

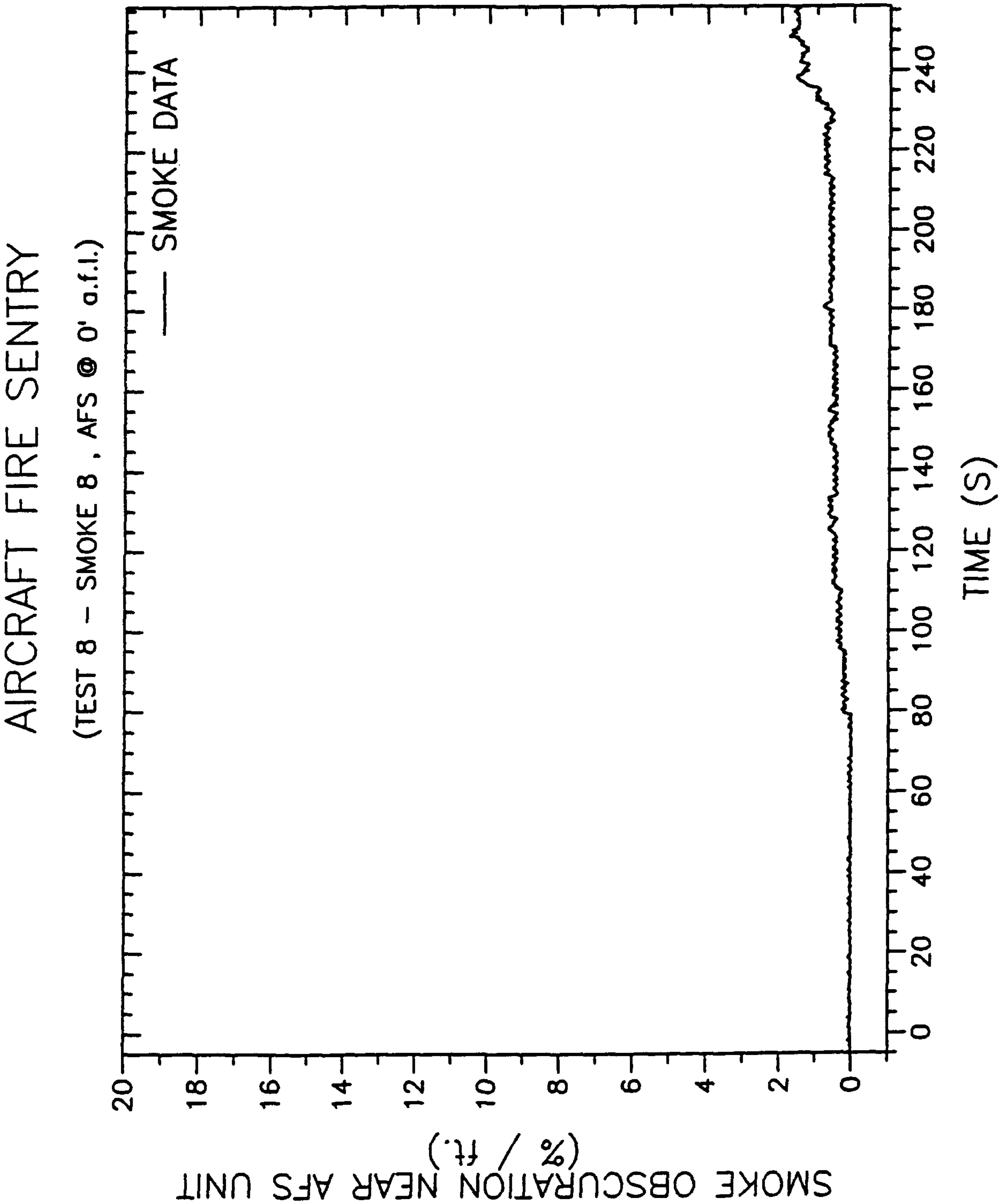


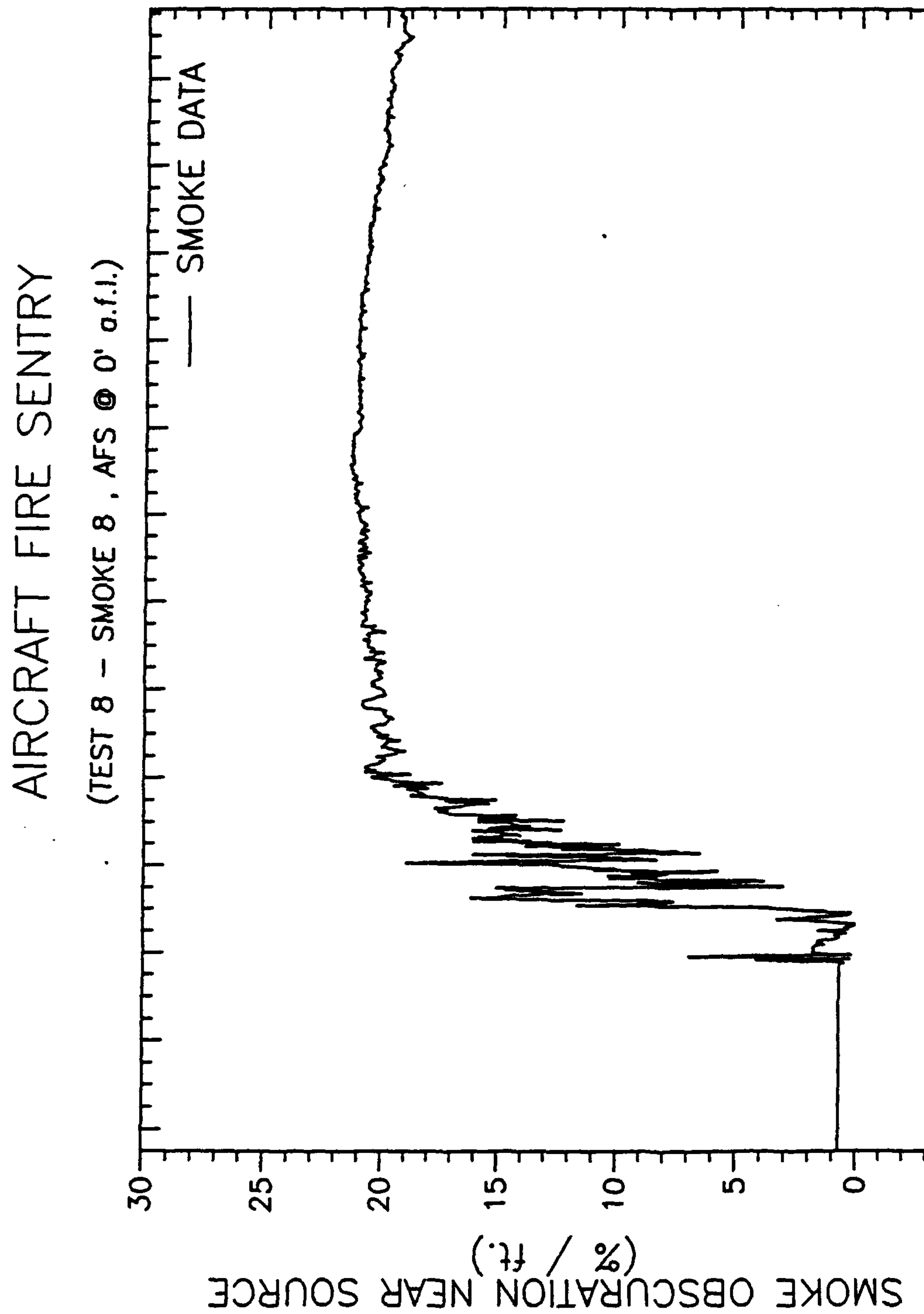
AIRCRAFT FIRE SENTRY

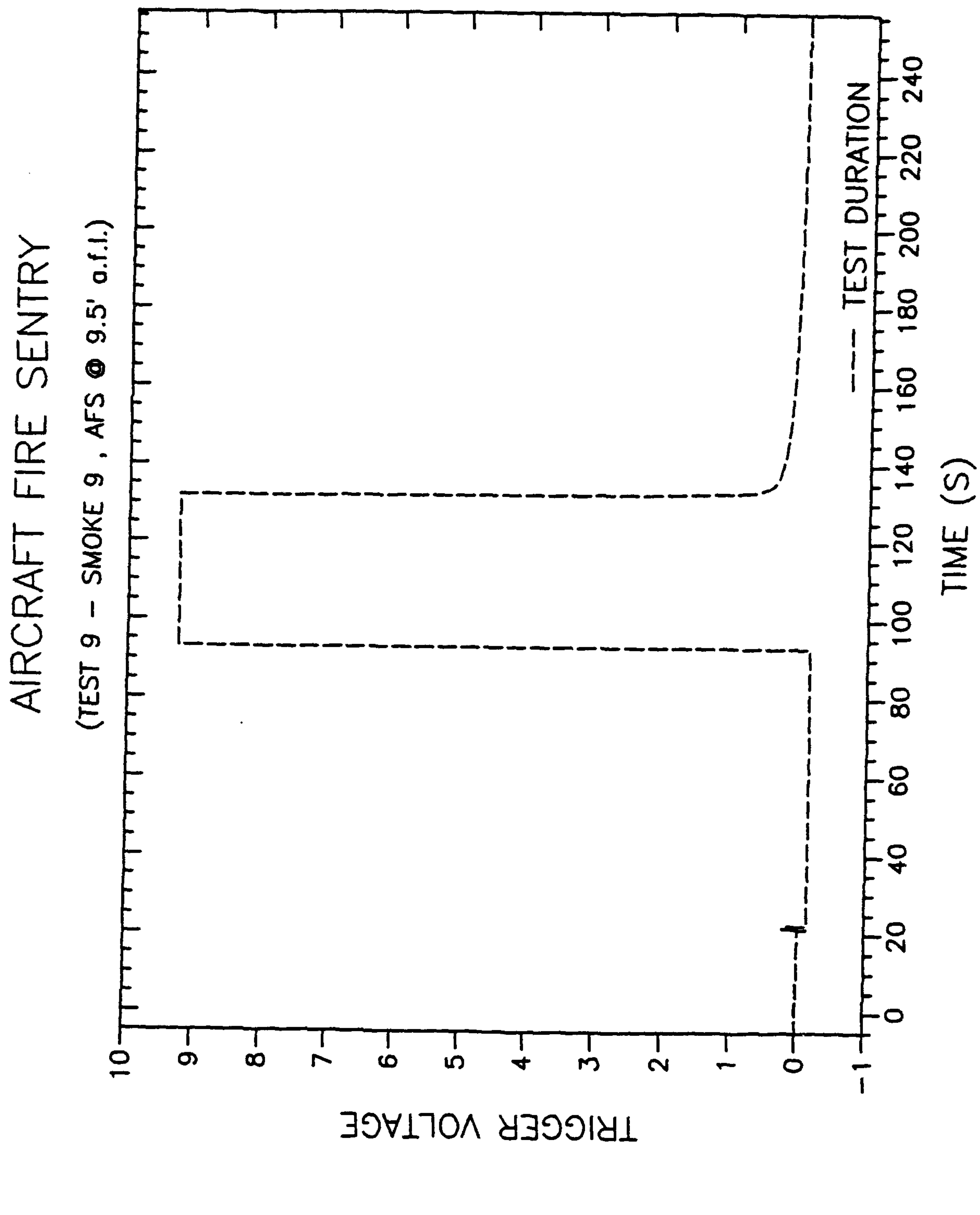
(TEST 7 – SMOKE 7 , AFS @ 0' a.f.l.)

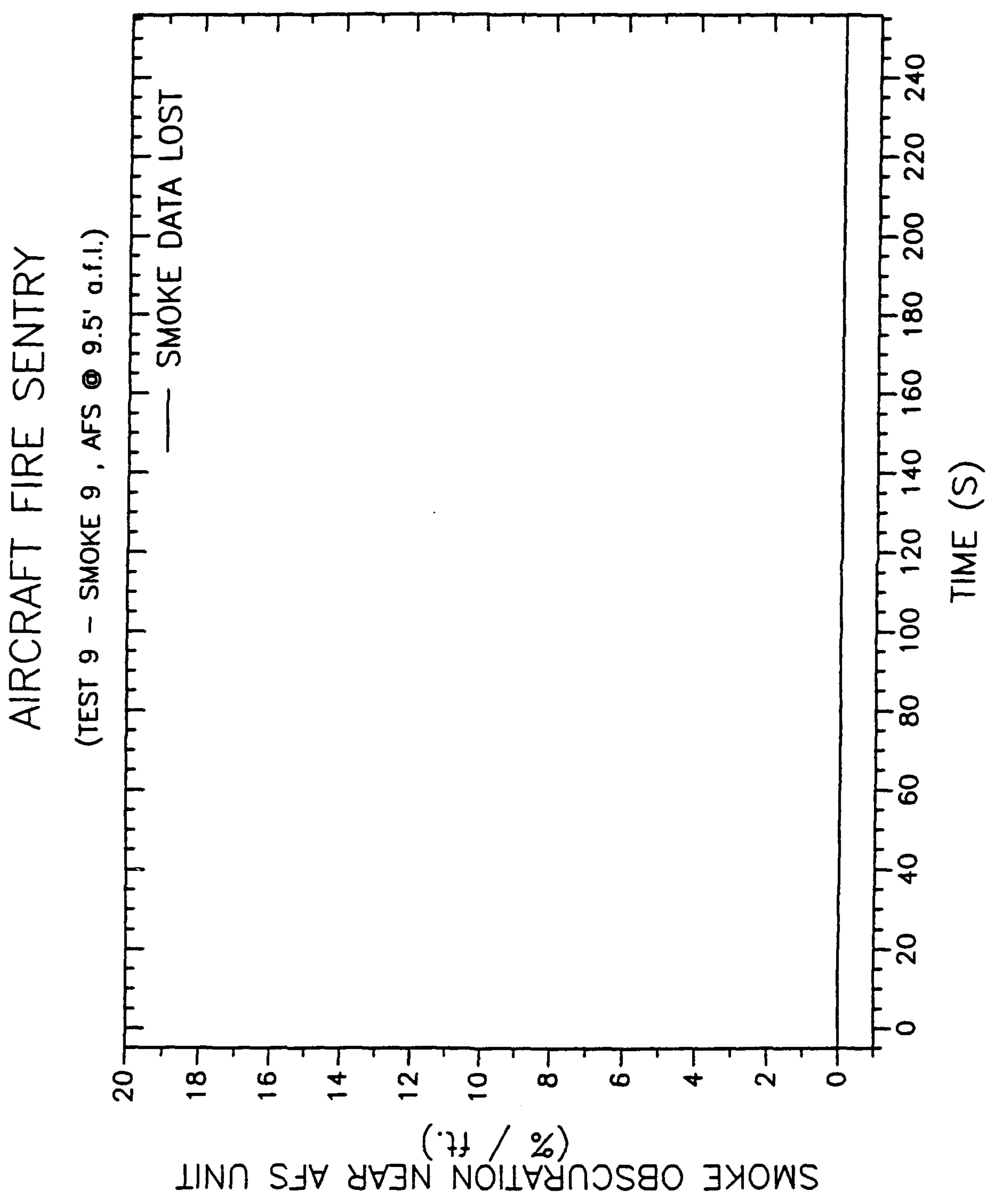



AIRCRAFT FIRE SENTRY
(TEST 8 - SMOKE 8 , AFS @ 0' a.f.l.)
TRIGGER VOLTAGE
TIME (S)
--- TEST DURATION
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
(TEST 8 - SMOKE 8 , AFS @ 0' a.f.l.)
SMOKE DATA
TIME (S)
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
2
4
6
8
10
12
14
16
18

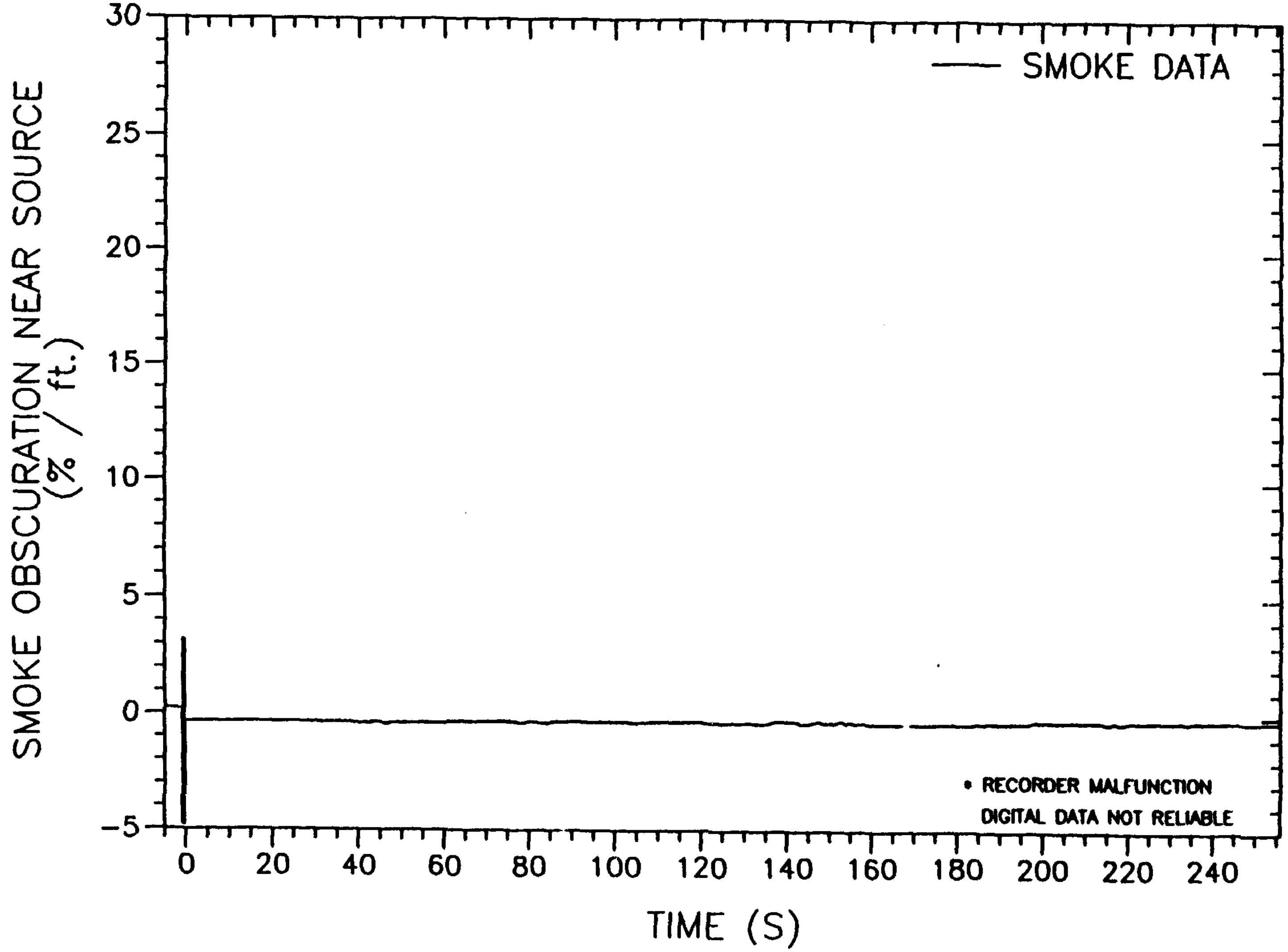

AIRCRAFT FIRE SENTRY
(TEST 8 – SMOKE 8 , AFS @ 0' a.f.l.)
— SMOKE DATA
SMOKE OBSCURATION NEAR SOURCE
(% / ft.)
TIME (S)
30
25
20
15
10
5
0
–5
0
20
40
60
80
100
120
140
160
180
200
220
240

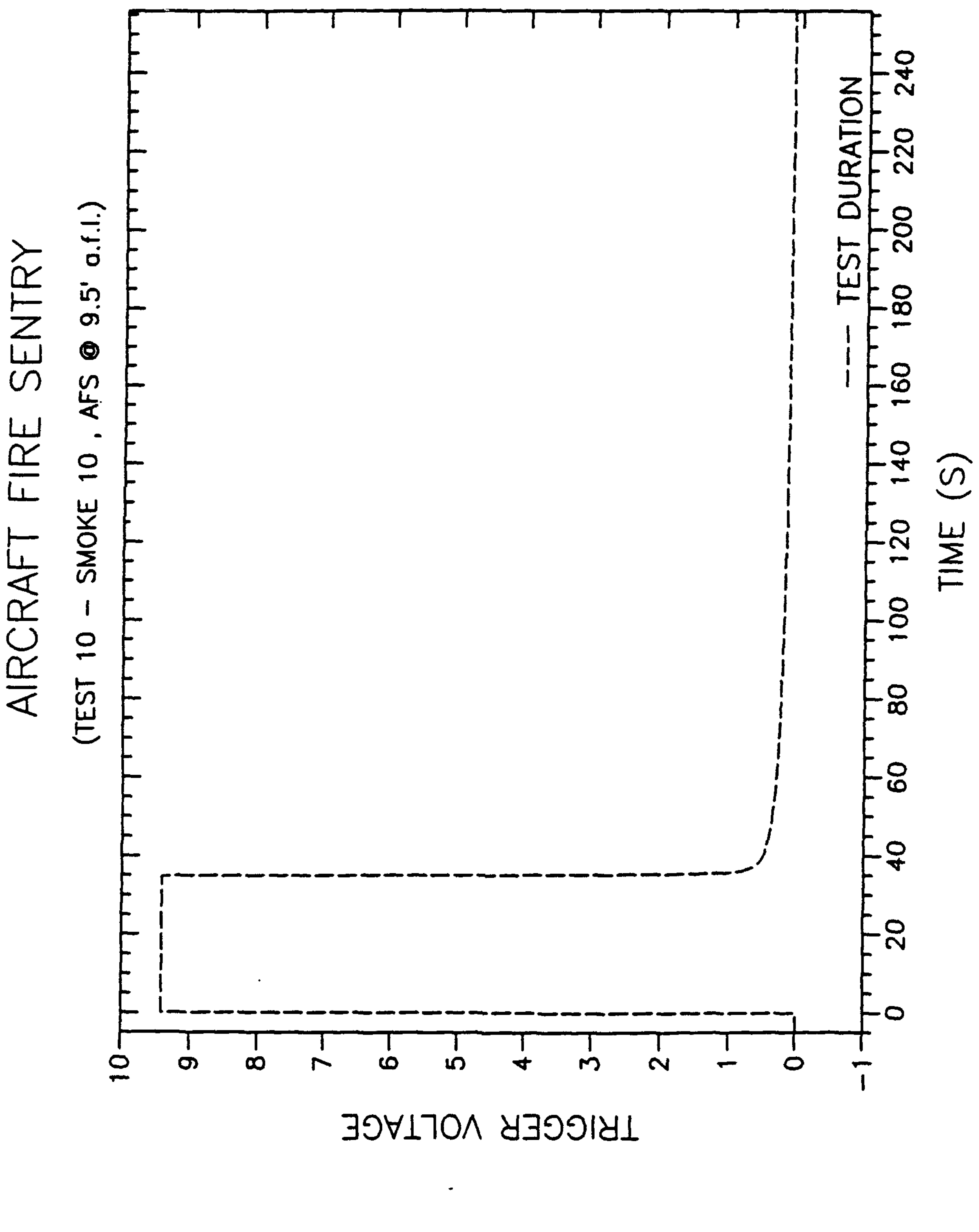

AIRCRAFT FIRE SENTRY
(TEST 9 – SMOKE 9 , AFS @ 9.5' a.f.l.)
TRIGGER VOLTAGE
TIME (S)
--- TEST DURATION
-1 0 1 2 3 4 5 6 7 8 9 10
0 20 40 60 80 100 120 140 160 180 200 220 240

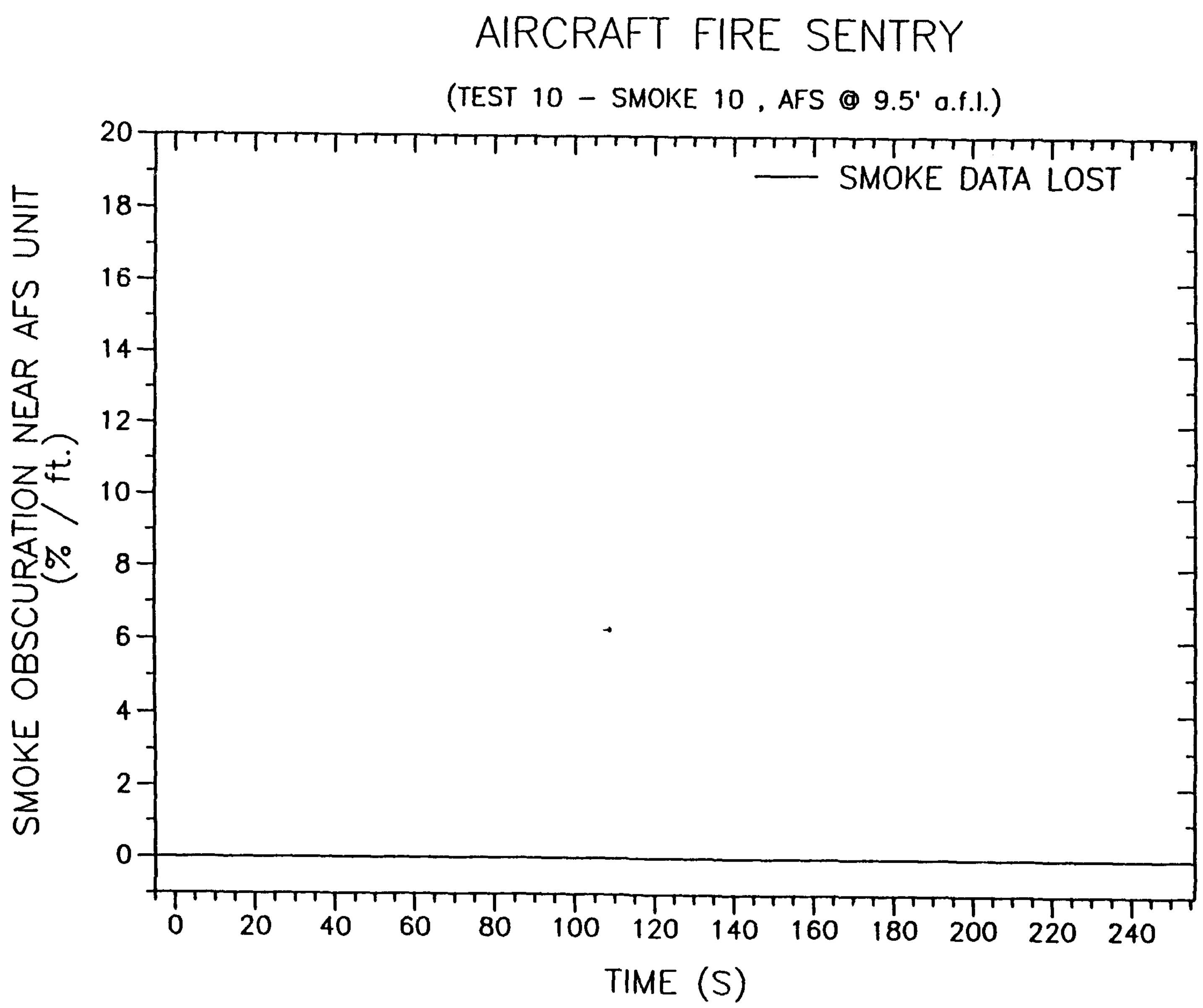

AIRCRAFT FIRE SENTRY
(TEST 9 – SMOKE 9 , AFS @ 9.5' a.f.l.)
— SMOKE DATA LOST
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
TIME (S)
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240

AIRCRAFT FIRE SENTRY

(TEST 9 – SMOKE 9 , AFS @ 9.5' a.f.l.)

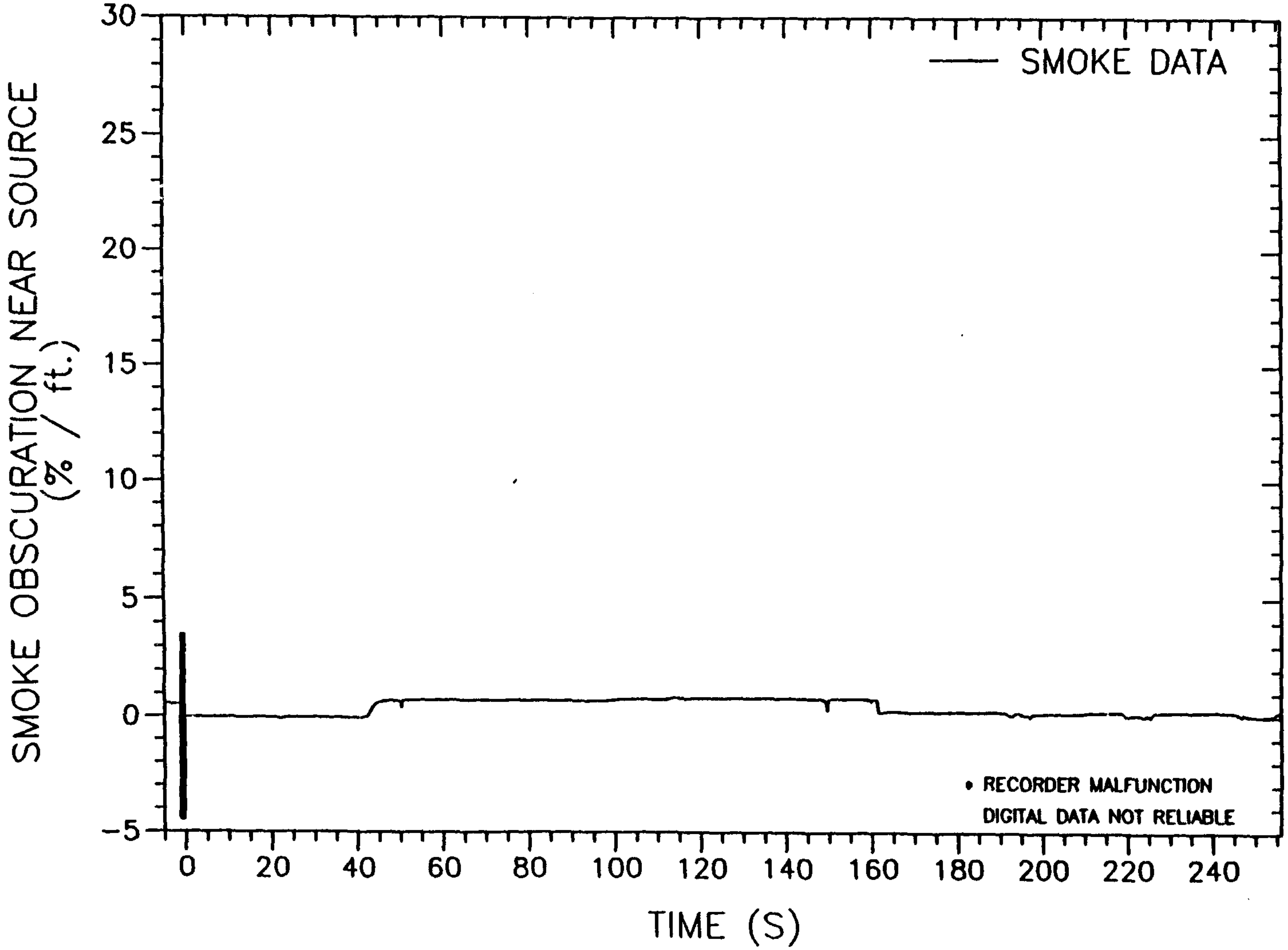


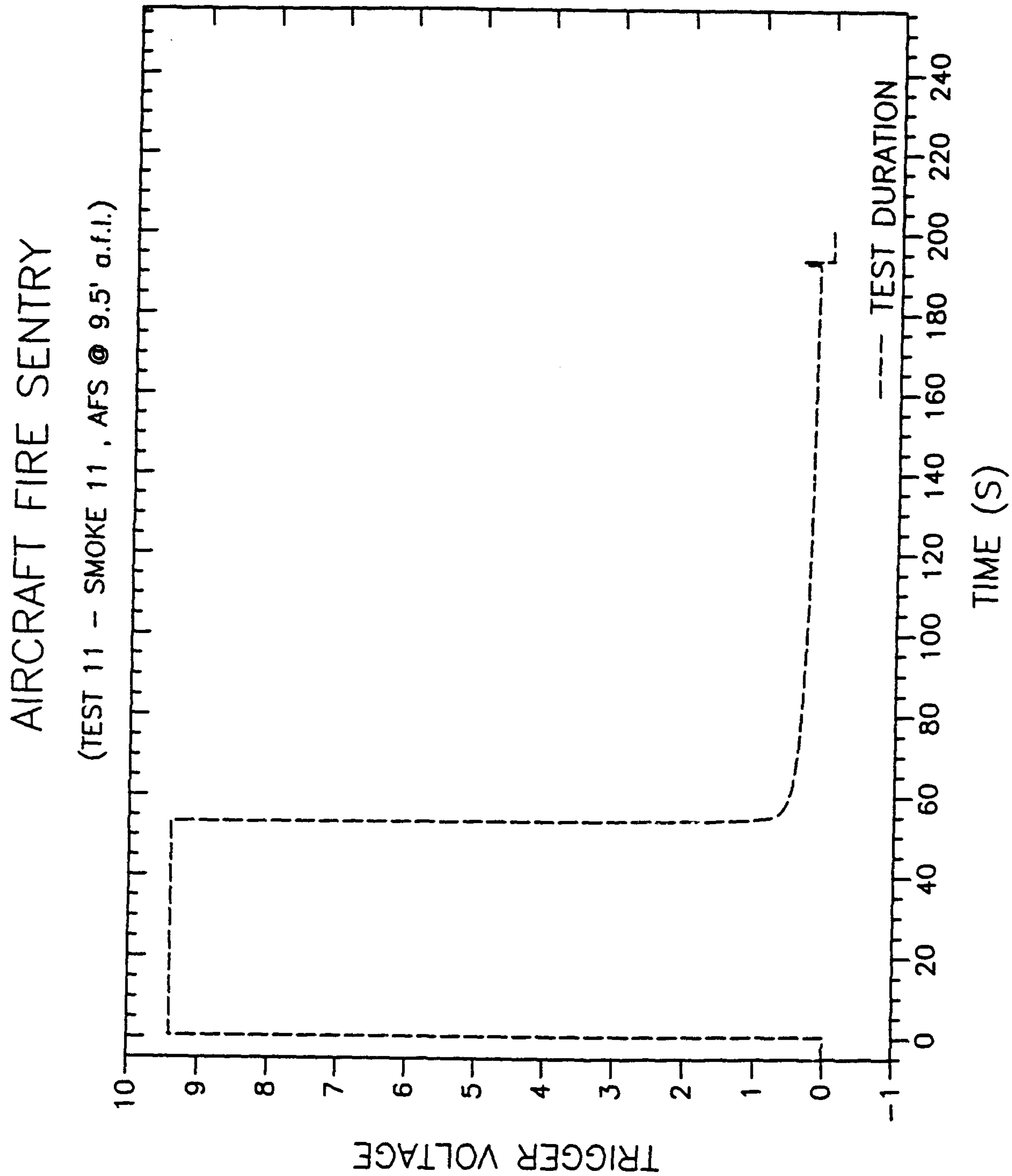

AIRCRAFT FIRE SENTRY
(TEST 10 – SMOKE 10 , AFS @ 9.5' a.f.l.)
TRIGGER VOLTAGE
TIME (S)
--- TEST DURATION
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
160
180
200
220
240

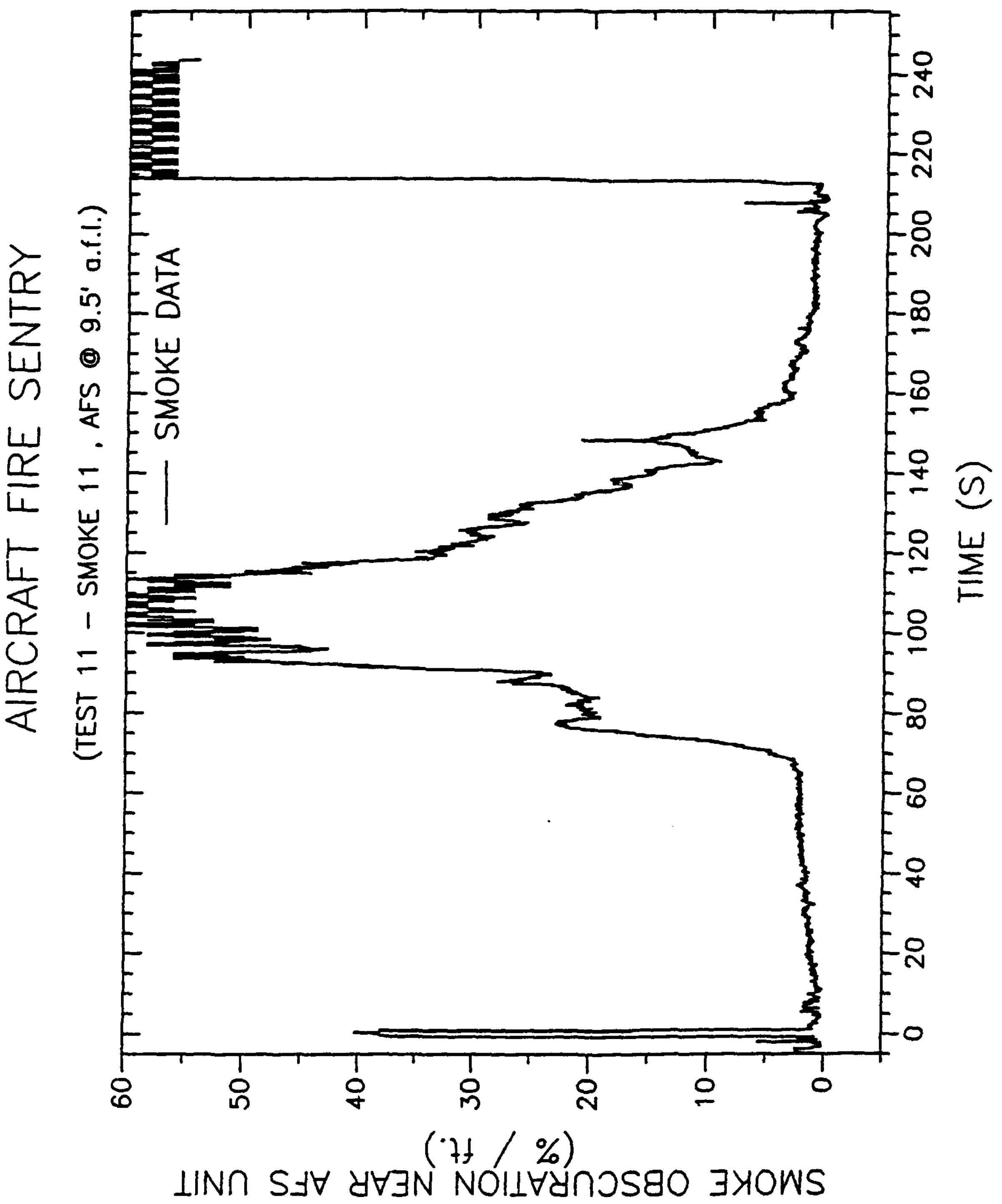

AIRCRAFT FIRE SENTRY
(TEST 10 – SMOKE 10 , AFS @ 9.5' a.f.l.)
SMOKE DATA LOST
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
0
2
4
6
8
10
12
14
16
18
20
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240

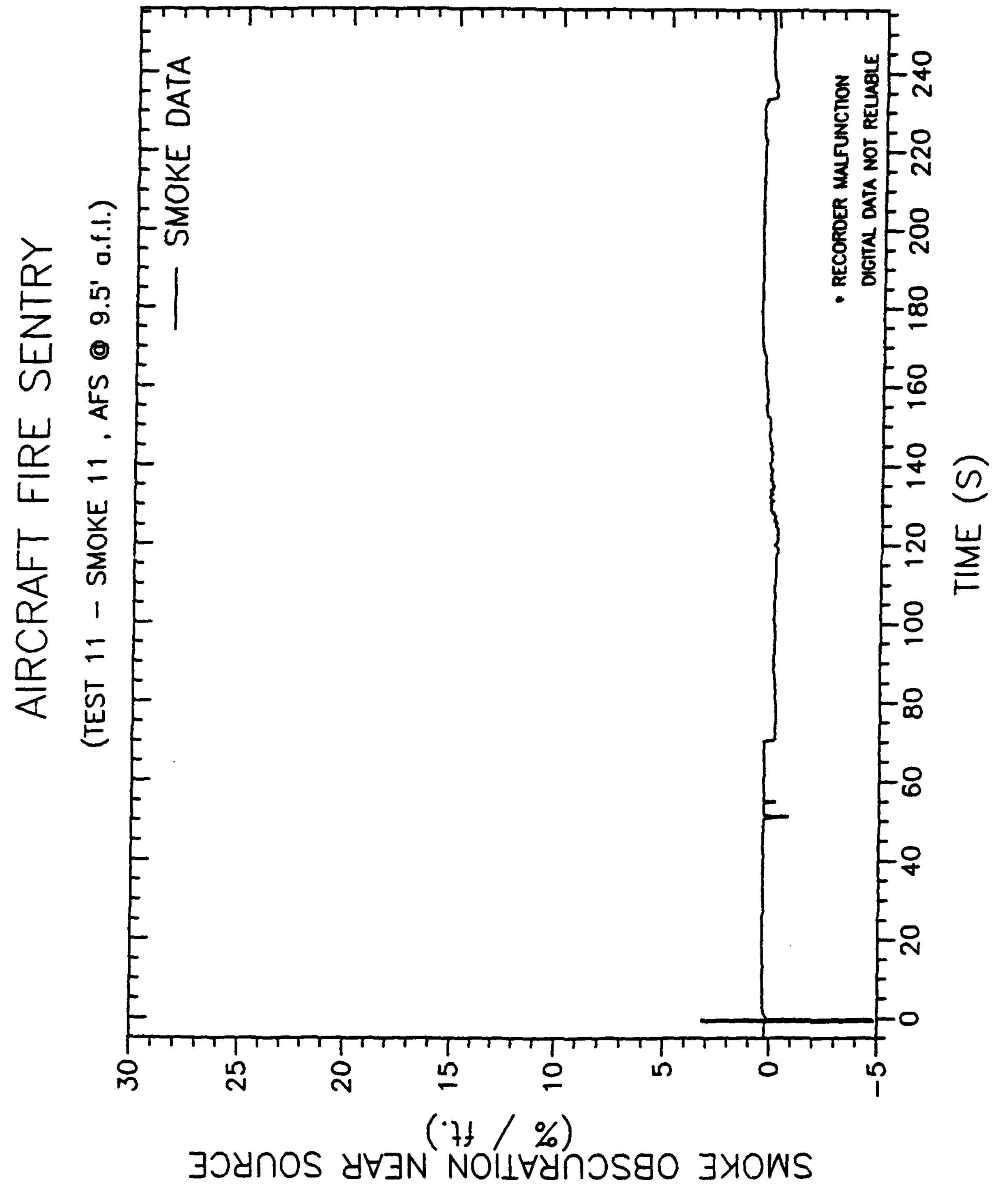
AIRCRAFT FIRE SENTRY

(TEST 10 – SMOKE 10 , AFS @ 9.5' a.f.l.)



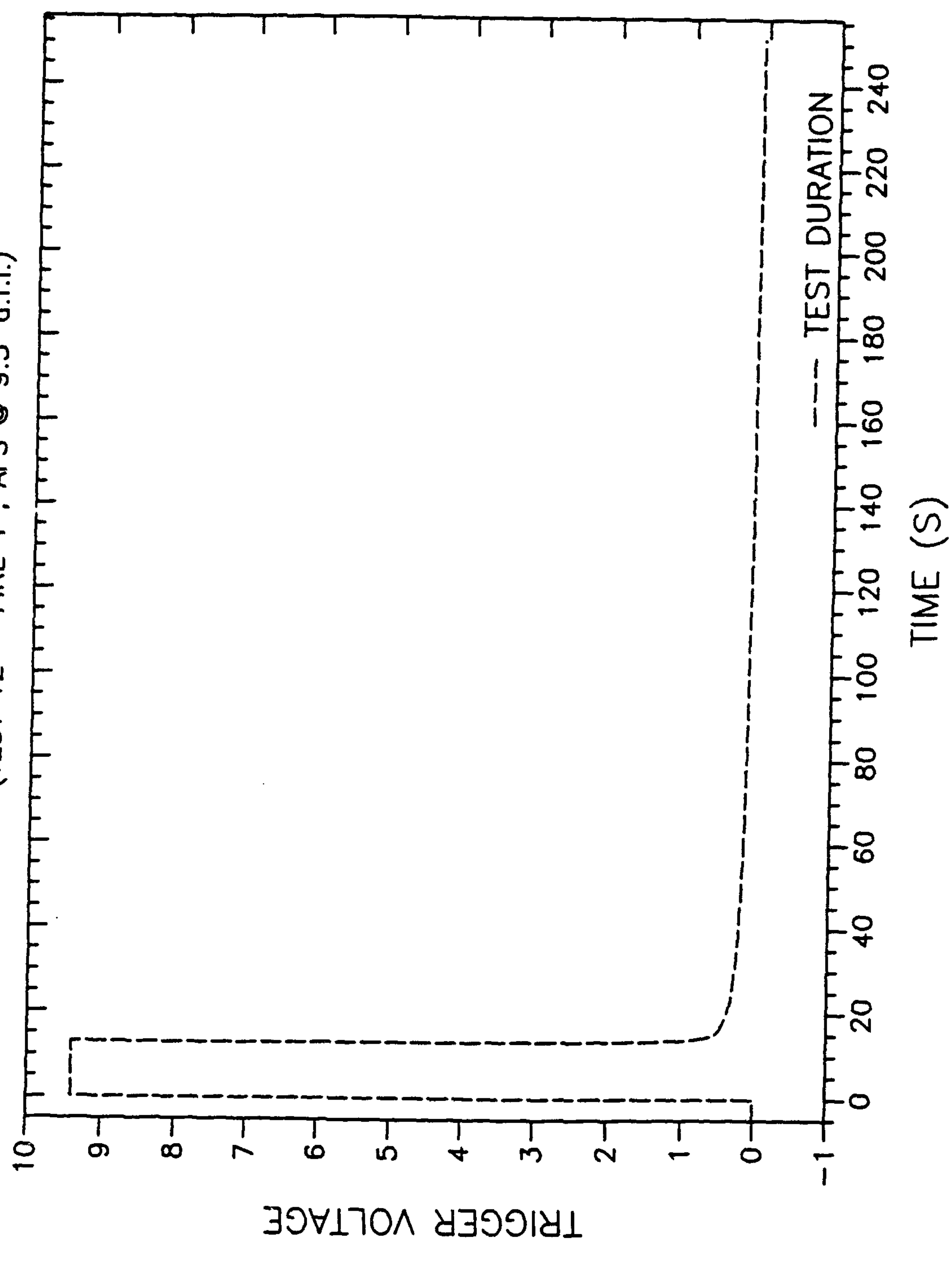

AIRCRAFT FIRE SENTRY
(TEST 11 - SMOKE 11 , AFS @ 9.5' a.f.l.)
TRIGGER VOLTAGE
TIME (S)
--- TEST DURATION
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
160
180
200
220
240

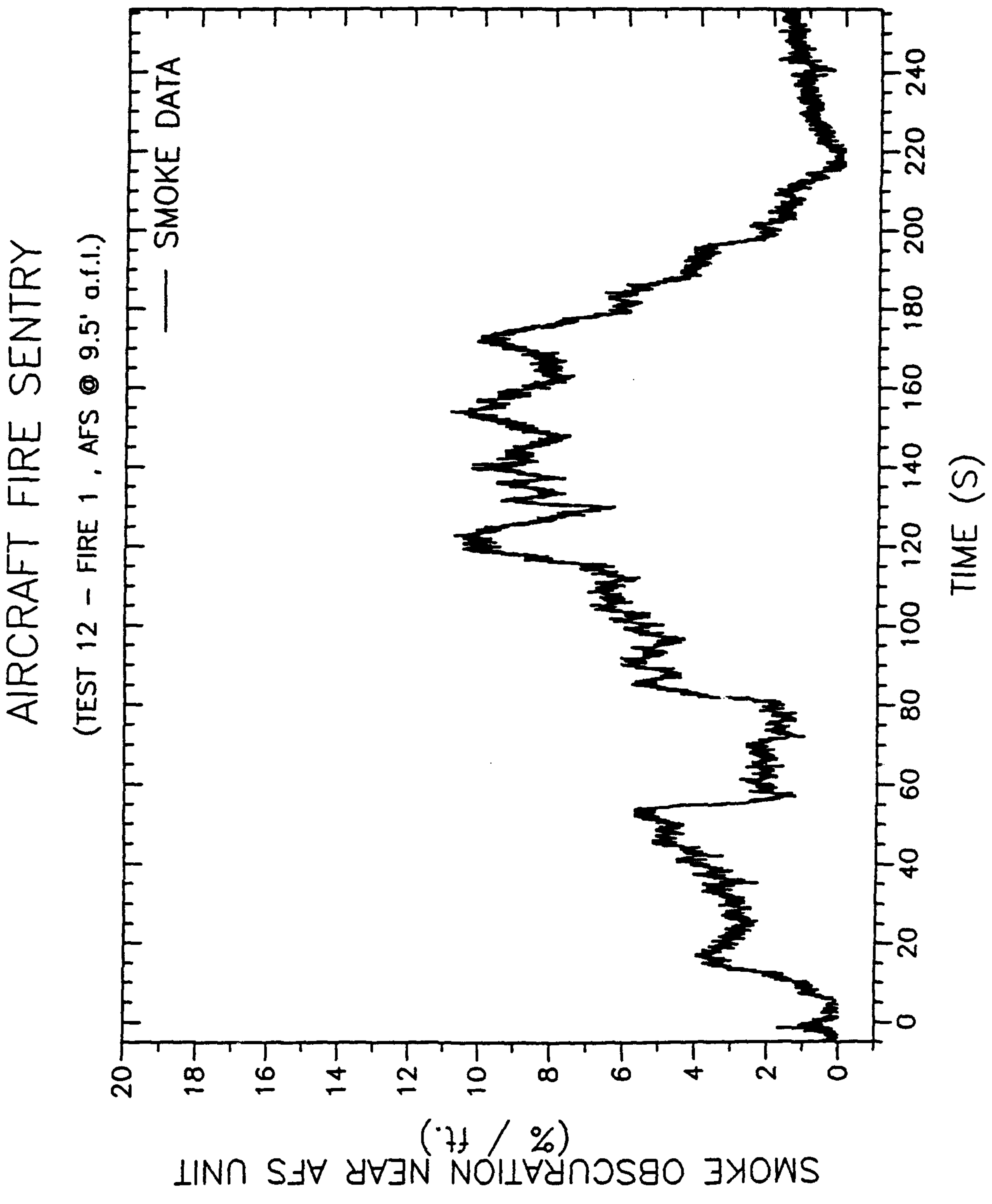

AIRCRAFT FIRE SENTRY
(TEST 11 - SMOKE 11 , AFS @ 9.5' a.f.l.)
— SMOKE DATA
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
TIME (S)
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
(TEST 11 - SMOKE 11 , AFS @ 9.5' a.f.l.)
— SMOKE DATA
• RECORDER MALFUNCTION
DIGITAL DATA NOT RELIABLE
SMOKE OBSCURATION NEAR SOURCE
(% / ft.)
TIME (S)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
140
160
180
200
220
240

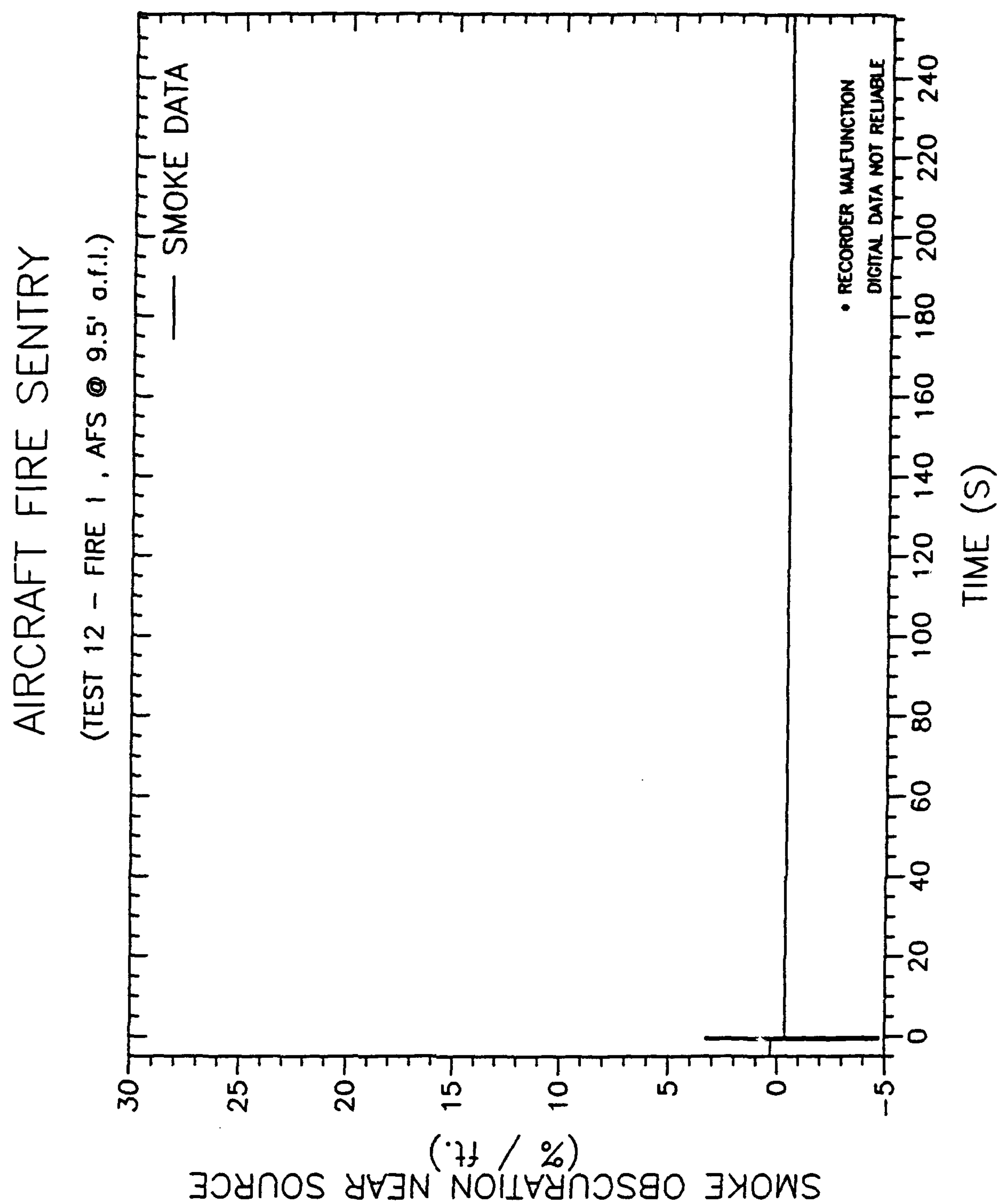
AIRCRAFT FIRE SENTRY

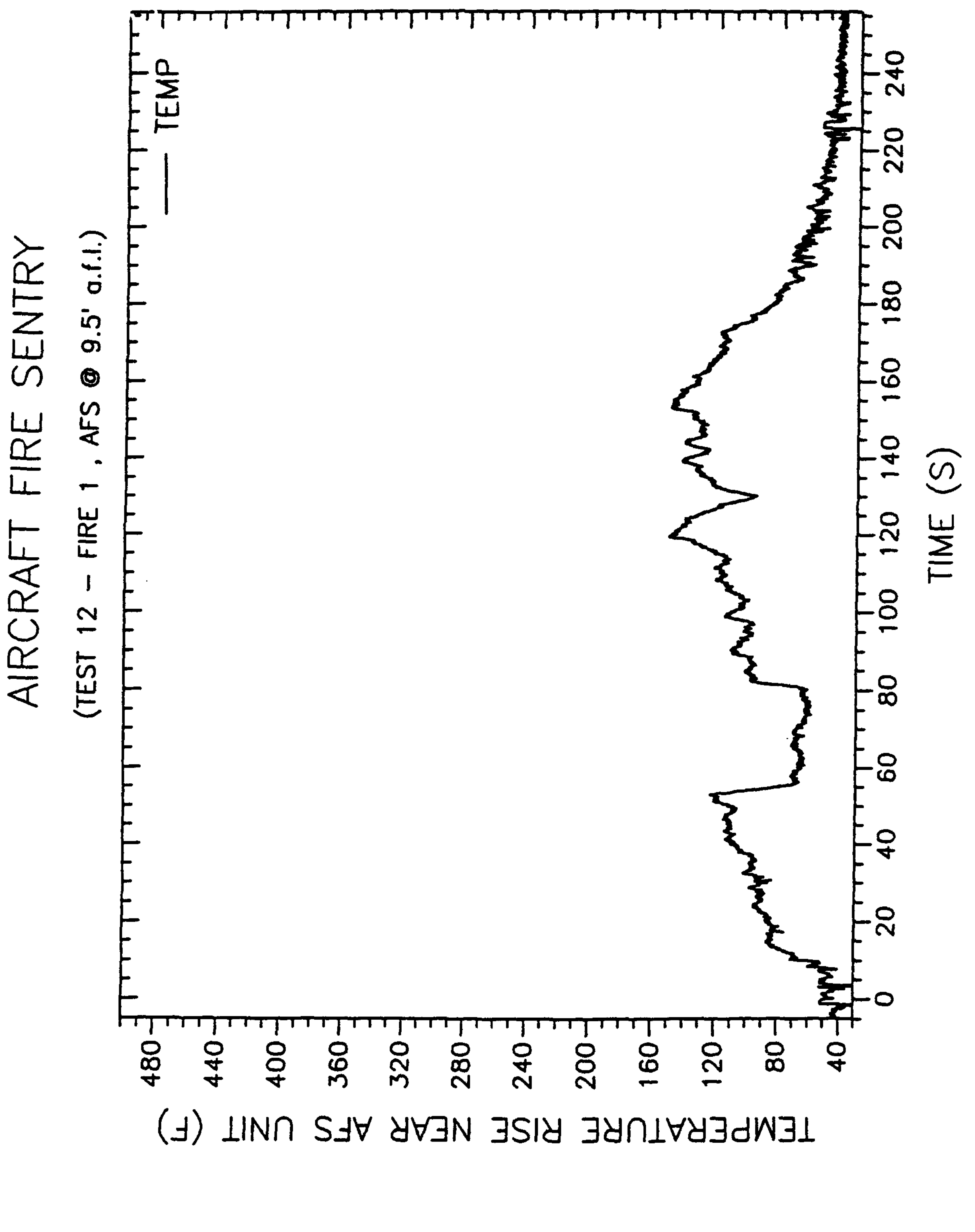
(TEST 12 – FIRE 1 , AFS @ 9.5' a.f.l.)

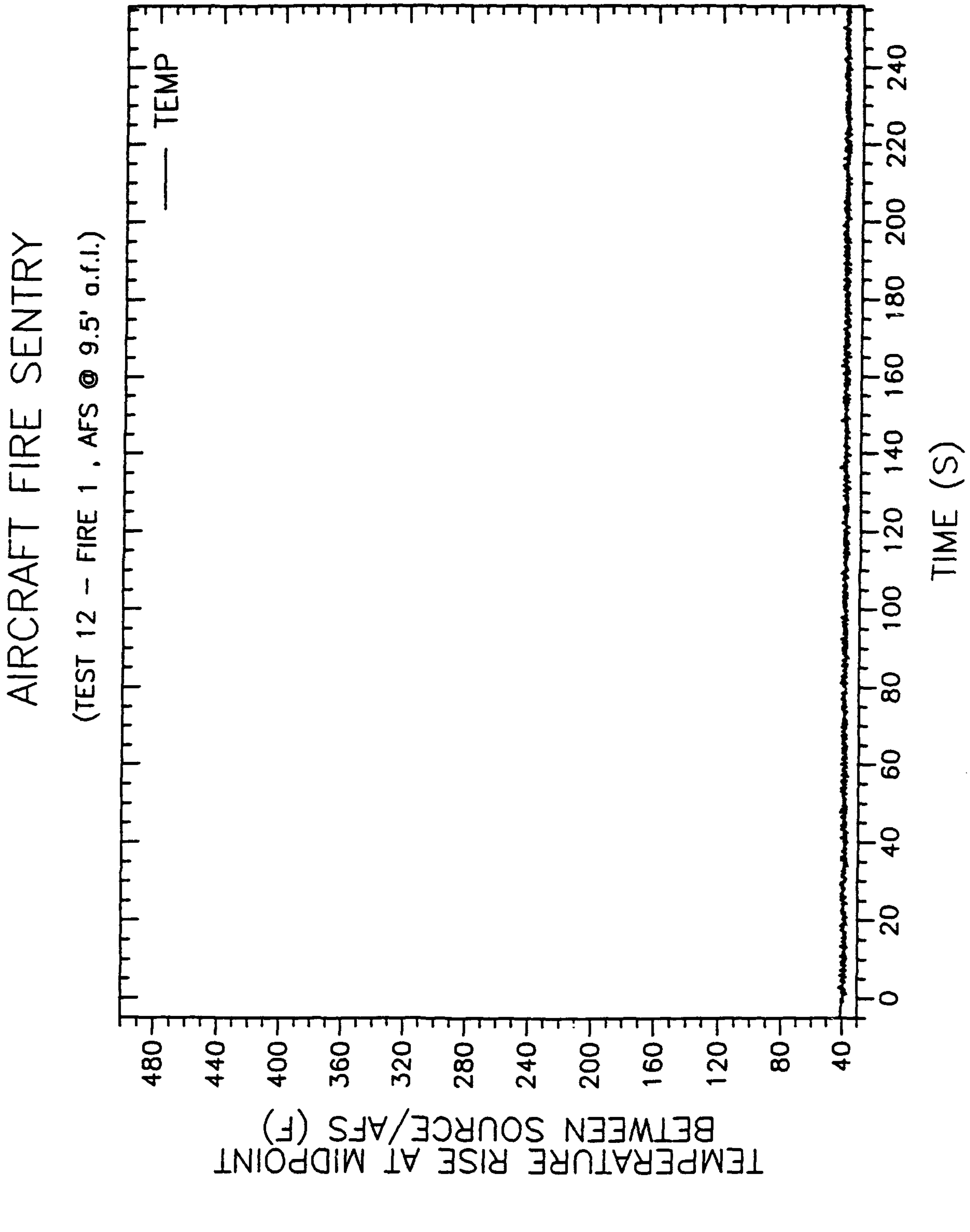


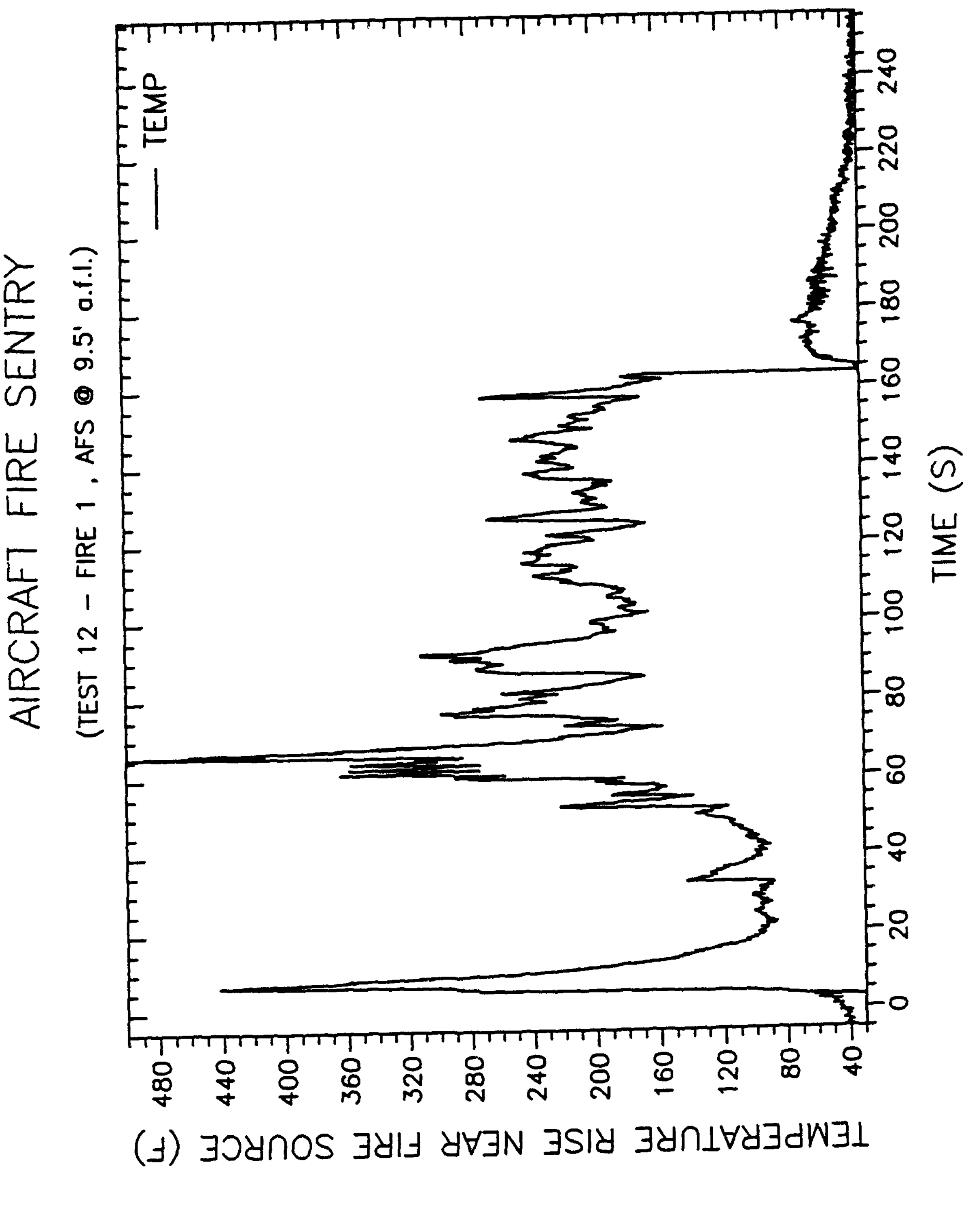


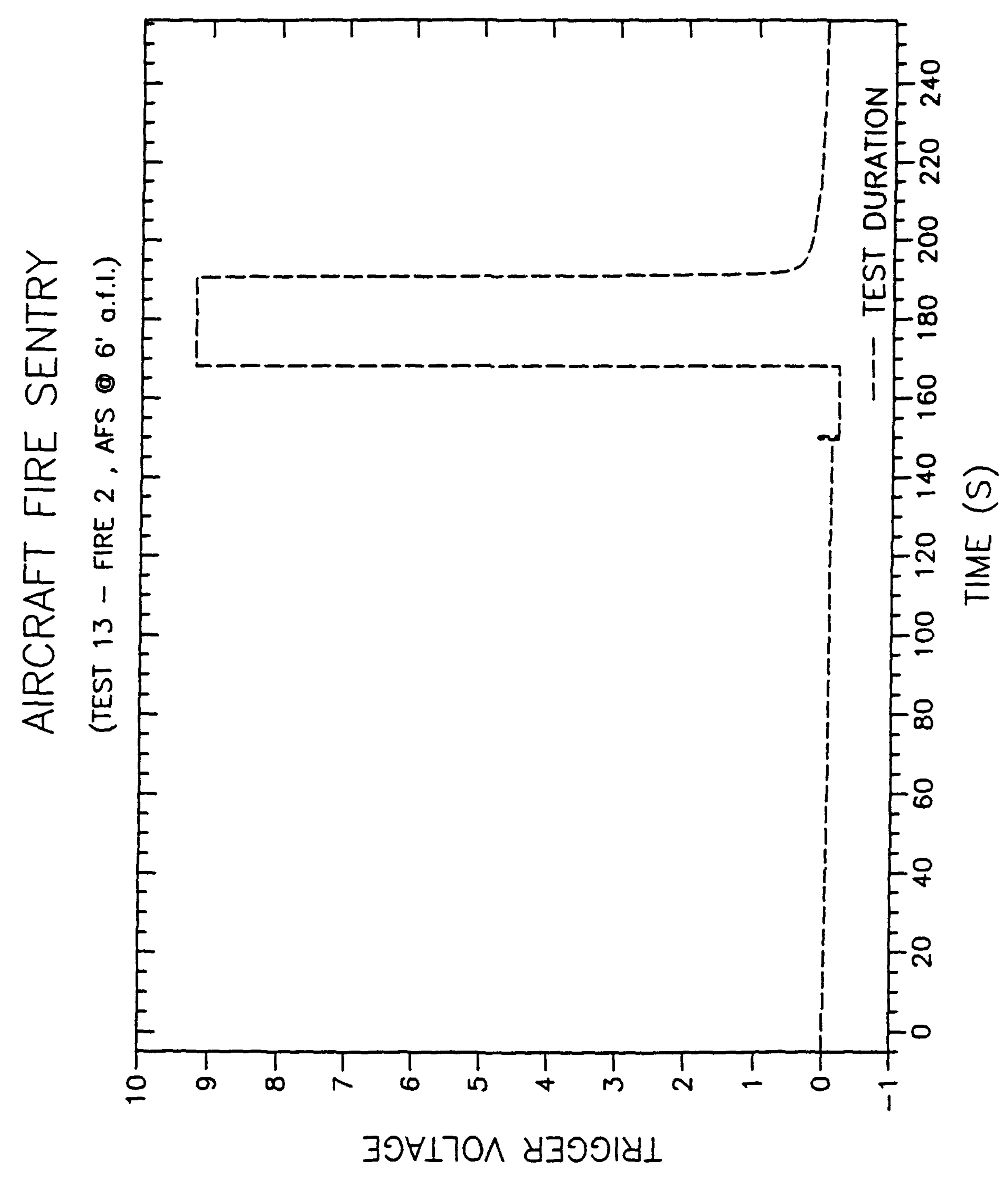
AIRCRAFT FIRE SENTRY
(TEST 12 – FIRE 1 , AFS @ 9.5' a.f.l.)
— SMOKE DATA
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
TIME (S)
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
(TEST 12 – FIRE 1 , AFS @ 9.5' a.f.l.)
SMOKE DATA
• RECORDER MALFUNCTION
DIGITAL DATA NOT RELIABLE
30
25
20
15
10
5
0
–5
SMOKE OBSCURATION NEAR SOURCE
(% / ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)


AIRCRAFT FIRE SENTRY
(TEST 12 – FIRE 1 , AFS @ 9.5' a.f.l.)
— TEMP
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240
TEMPERATURE RISE NEAR AFS UNIT (F)
40
80
120
160
200
240
280
320
360
400
440
480

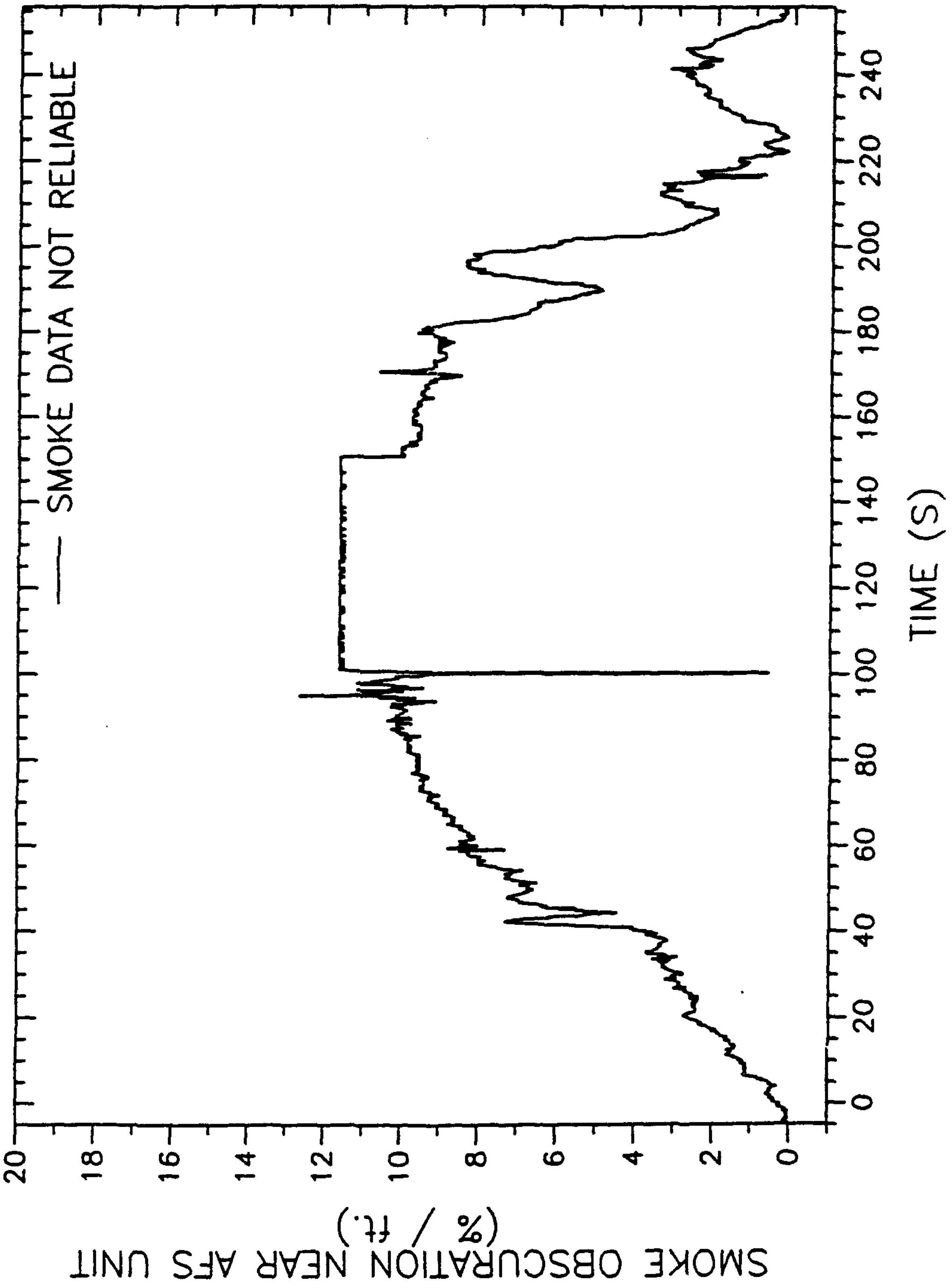

AIRCRAFT FIRE SENTRY
(TEST 12 - FIRE 1 , AFS @ 9.5' a.f.l.)
TEMP
TIME (S)
TEMPERATURE RISE AT MIDPOINT BETWEEN SOURCE/AFS (F)
0
20
40
60
80
100
120
140
160
180
200
220
240
40
80
120
160
200
240
280
320
360
400
440
480


AIRCRAFT FIRE SENTRY
(TEST 12 - FIRE 1 , AFS @ 9.5' a.f.l.)
TEMP
TIME (S)
TEMPERATURE RISE NEAR FIRE SOURCE (F)
0
20
40
60
80
100
120
140
160
180
200
220
240
40
80
120
160
200
240
280
320
360
400
440
480


AIRCRAFT FIRE SENTRY
(TEST 13 – FIRE 2 , AFS @ 6' a.f.l.)
TRIGGER VOLTAGE
TIME (S)
---- TEST DURATION
10
9
8
7
6
5
4
3
2
1
0
–1
0
20
40
60
80
100
120
140
160
180
200
220
240

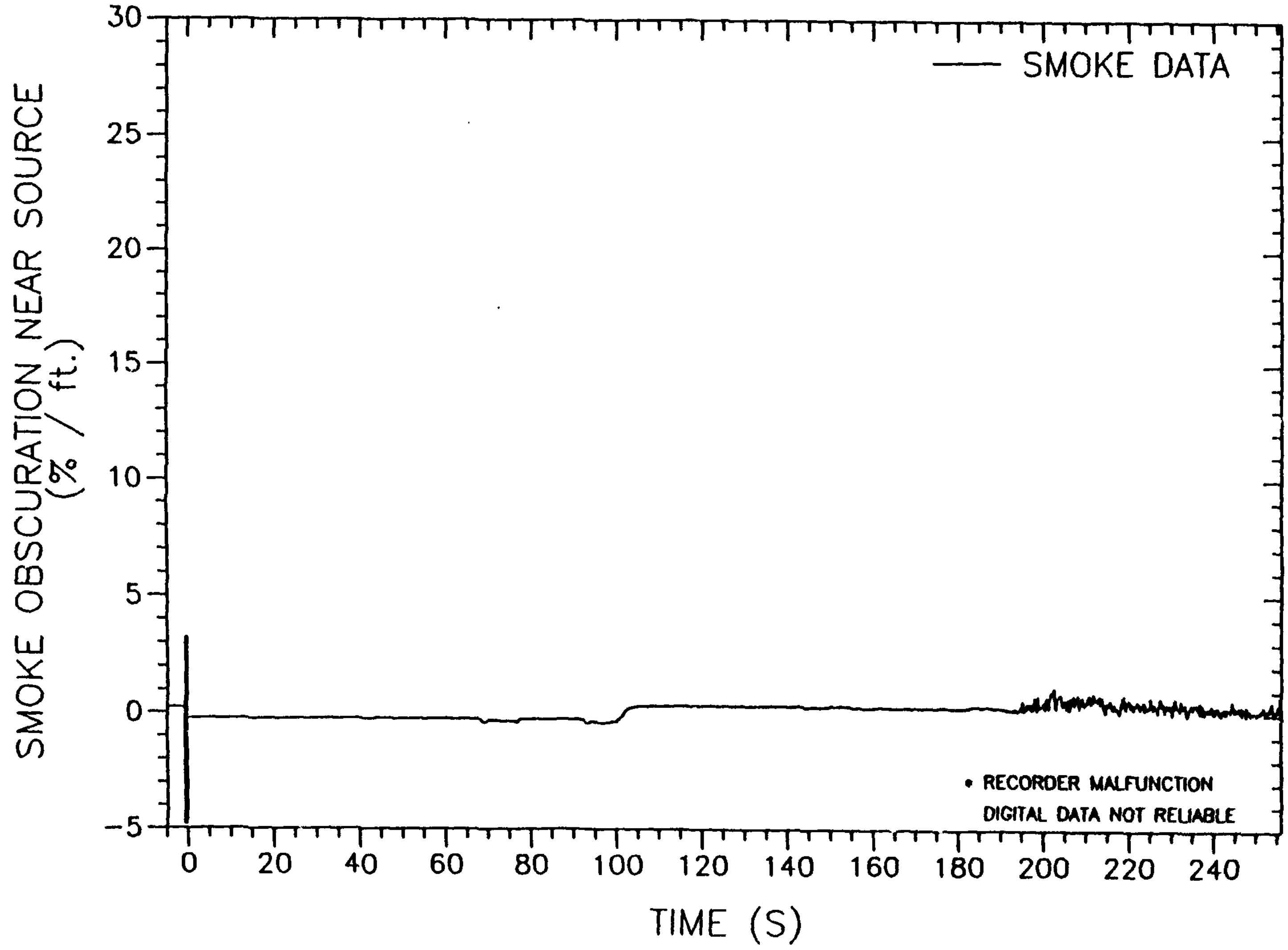
AIRCRAFT FIRE SENTRY

(TEST 13 – FIRE 2 , AFS @ 6' a.f.l.)



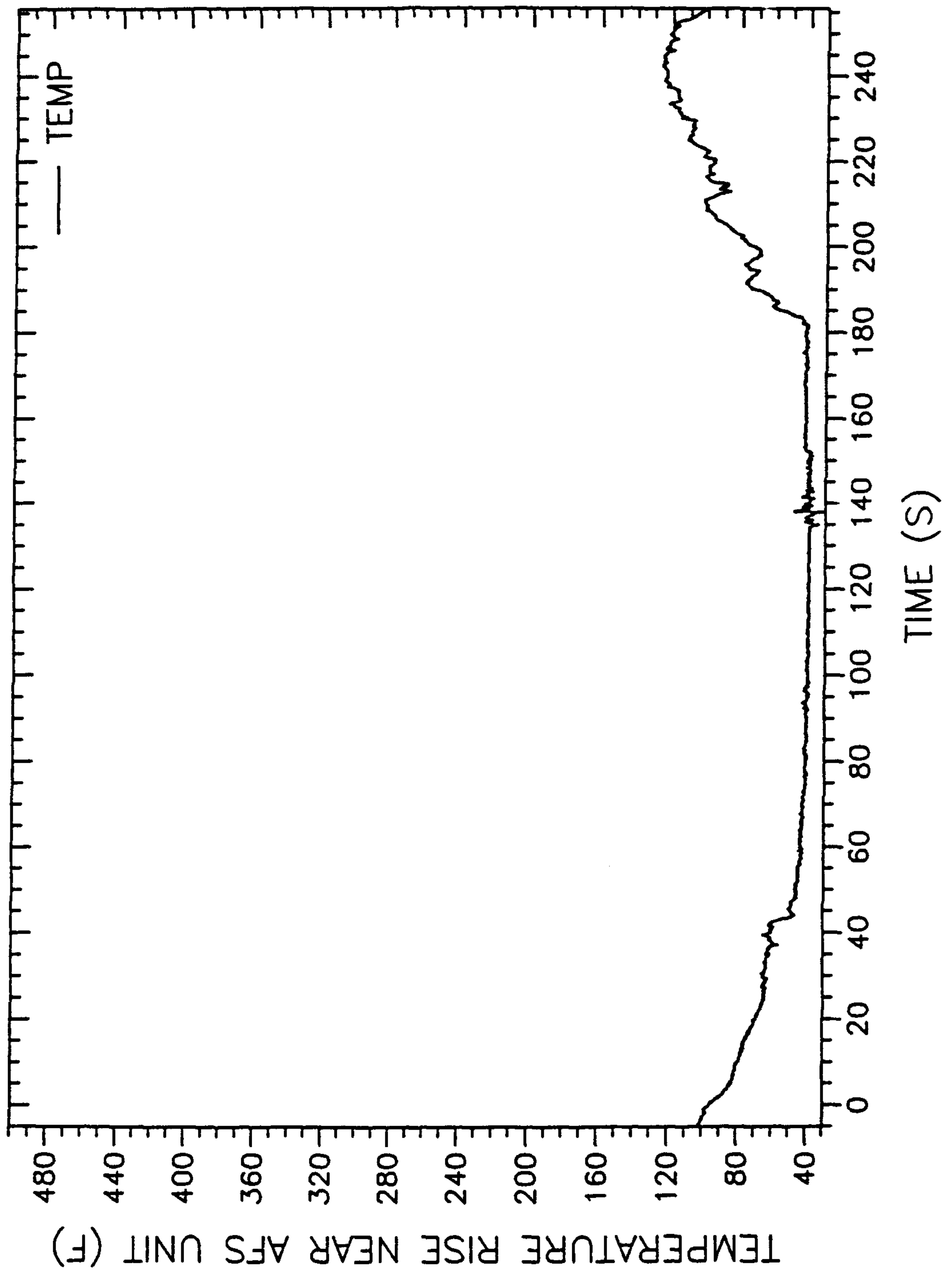
AIRCRAFT FIRE SENTRY

(TEST 13 - FIRE 2 , AFS @ 6' a.f.l.)



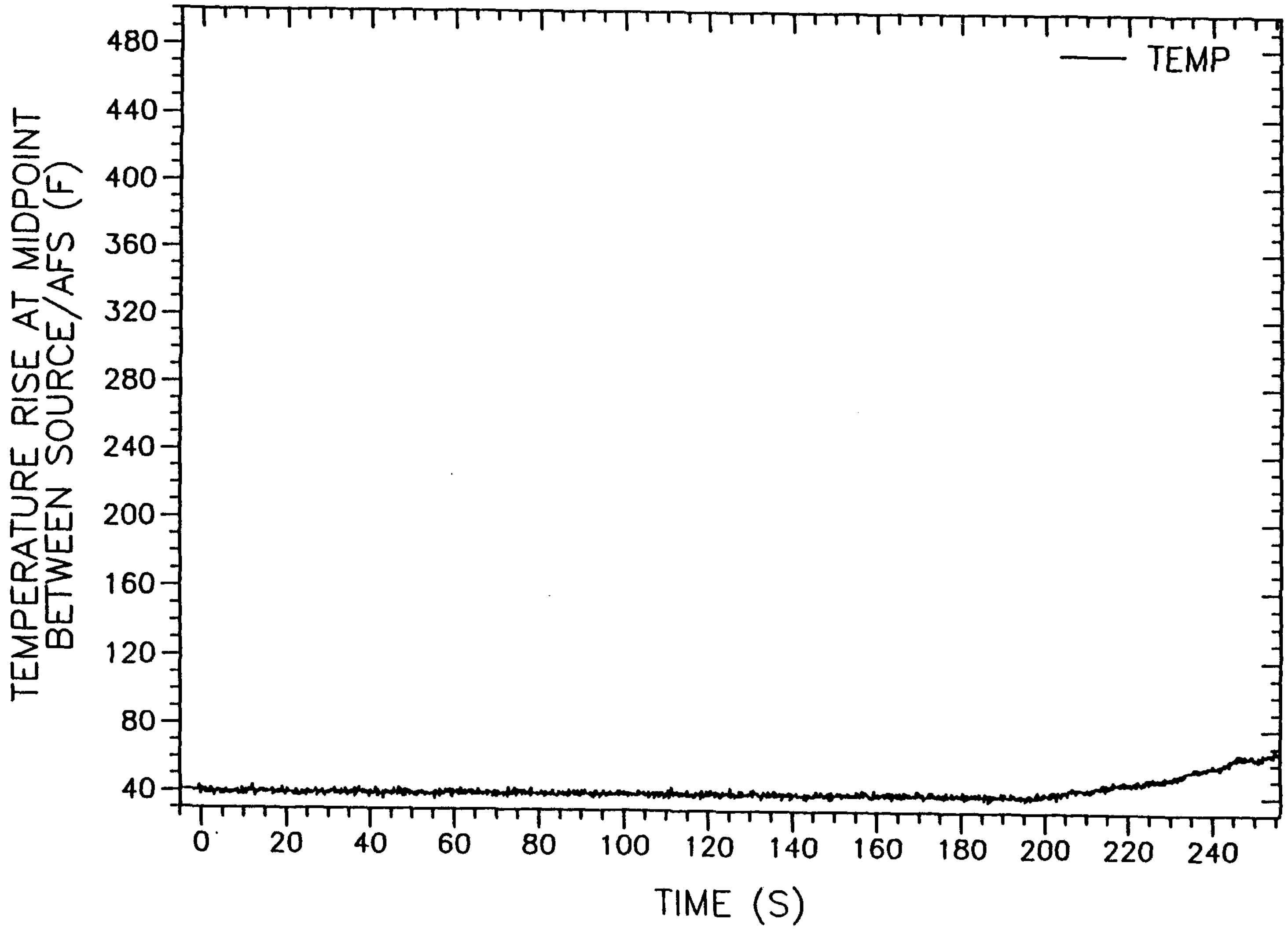
AIRCRAFT FIRE SENTRY

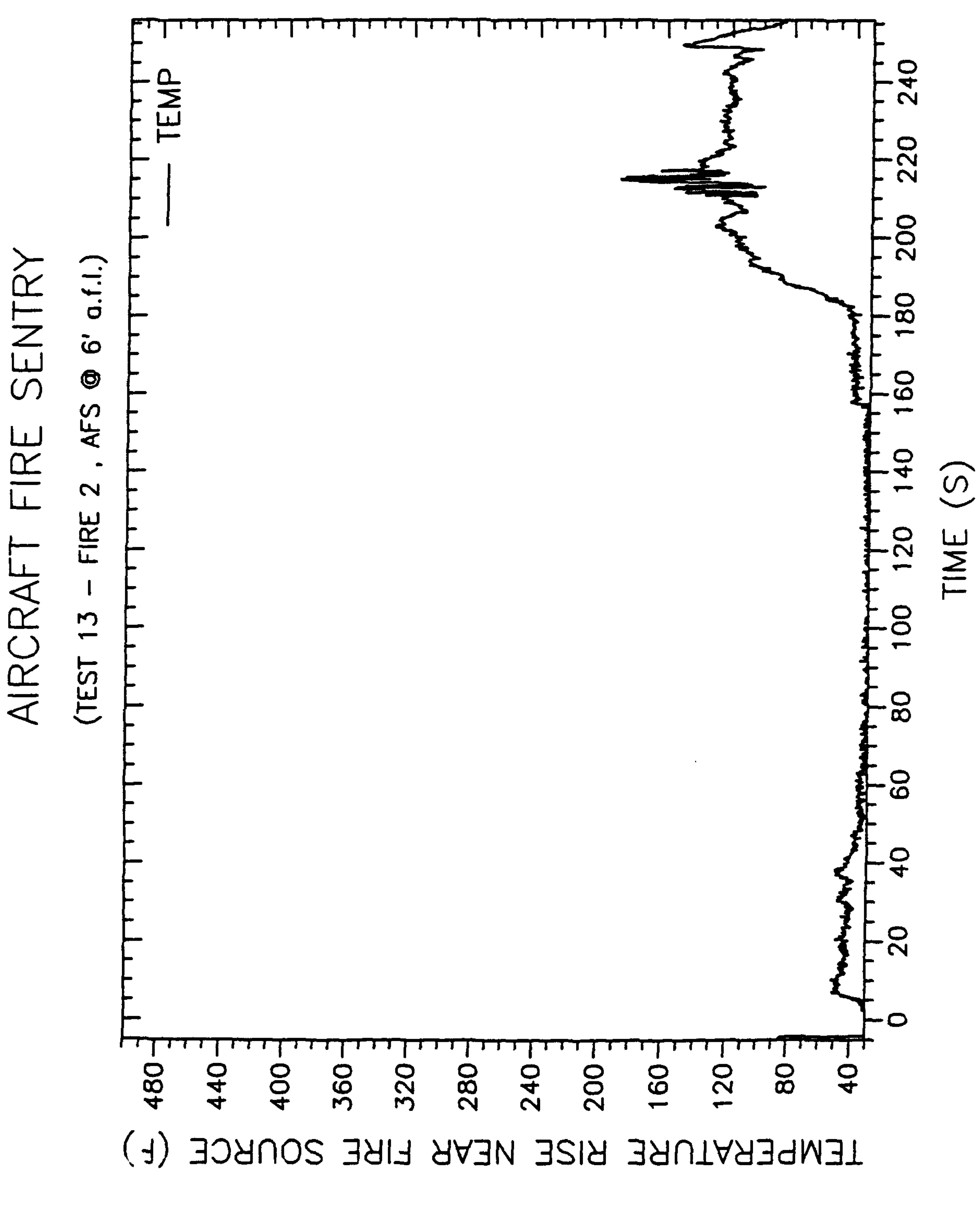
(TEST 13 – FIRE 2 , AFS @ 6' a.f.l.)



AIRCRAFT FIRE SENTRY

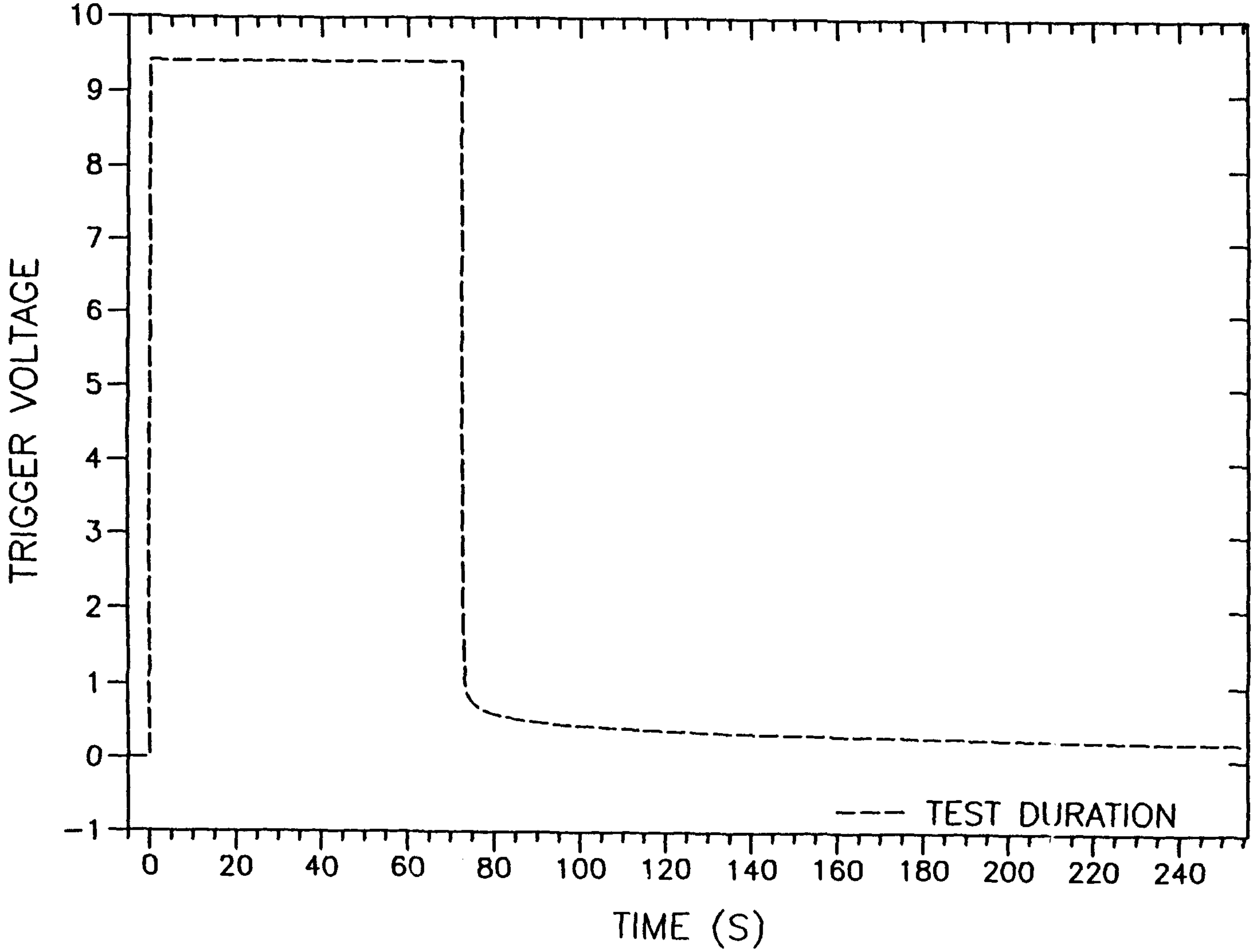
(TEST 13 – FIRE 2 , AFS @ 6' a.f.l.)

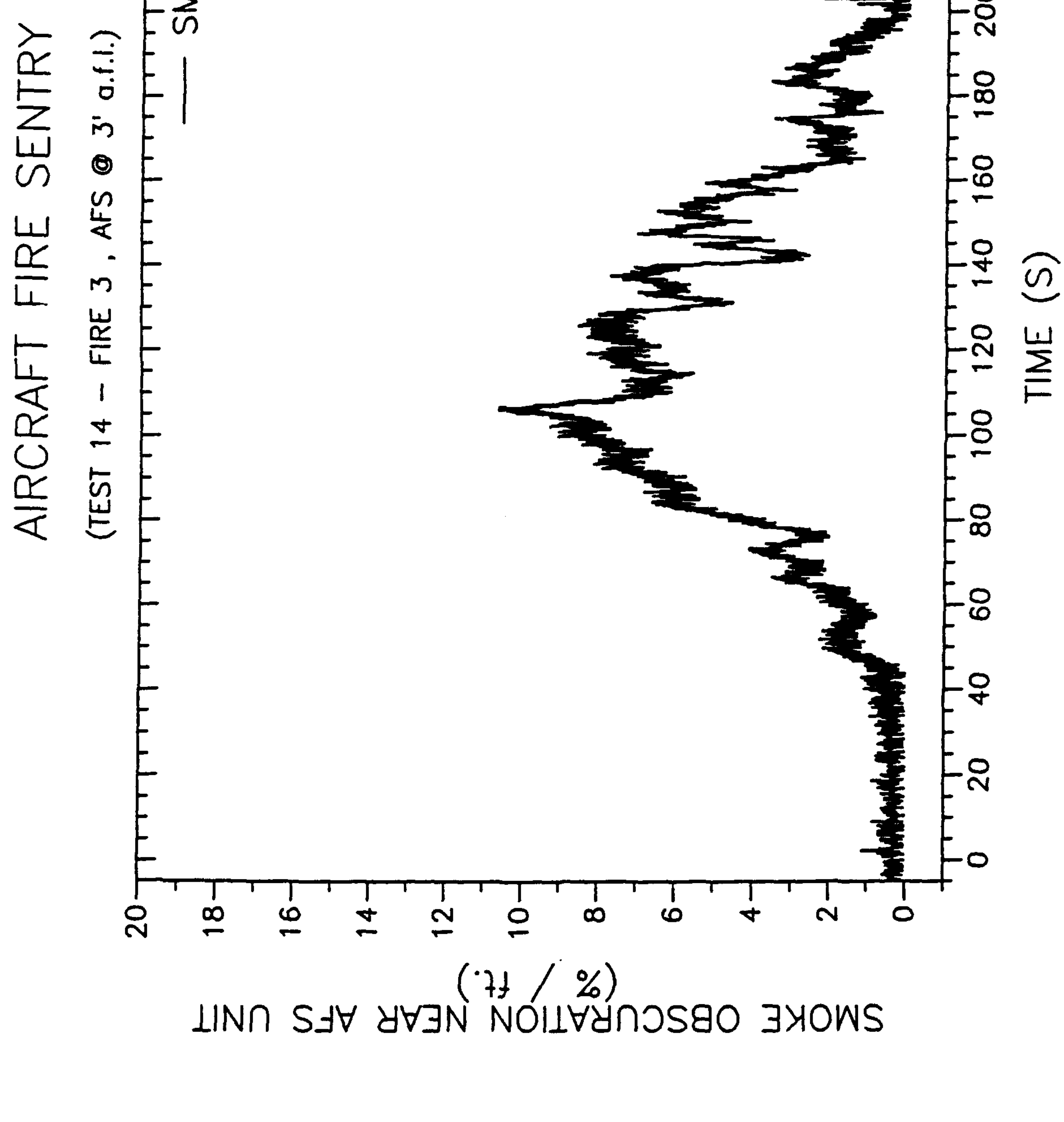


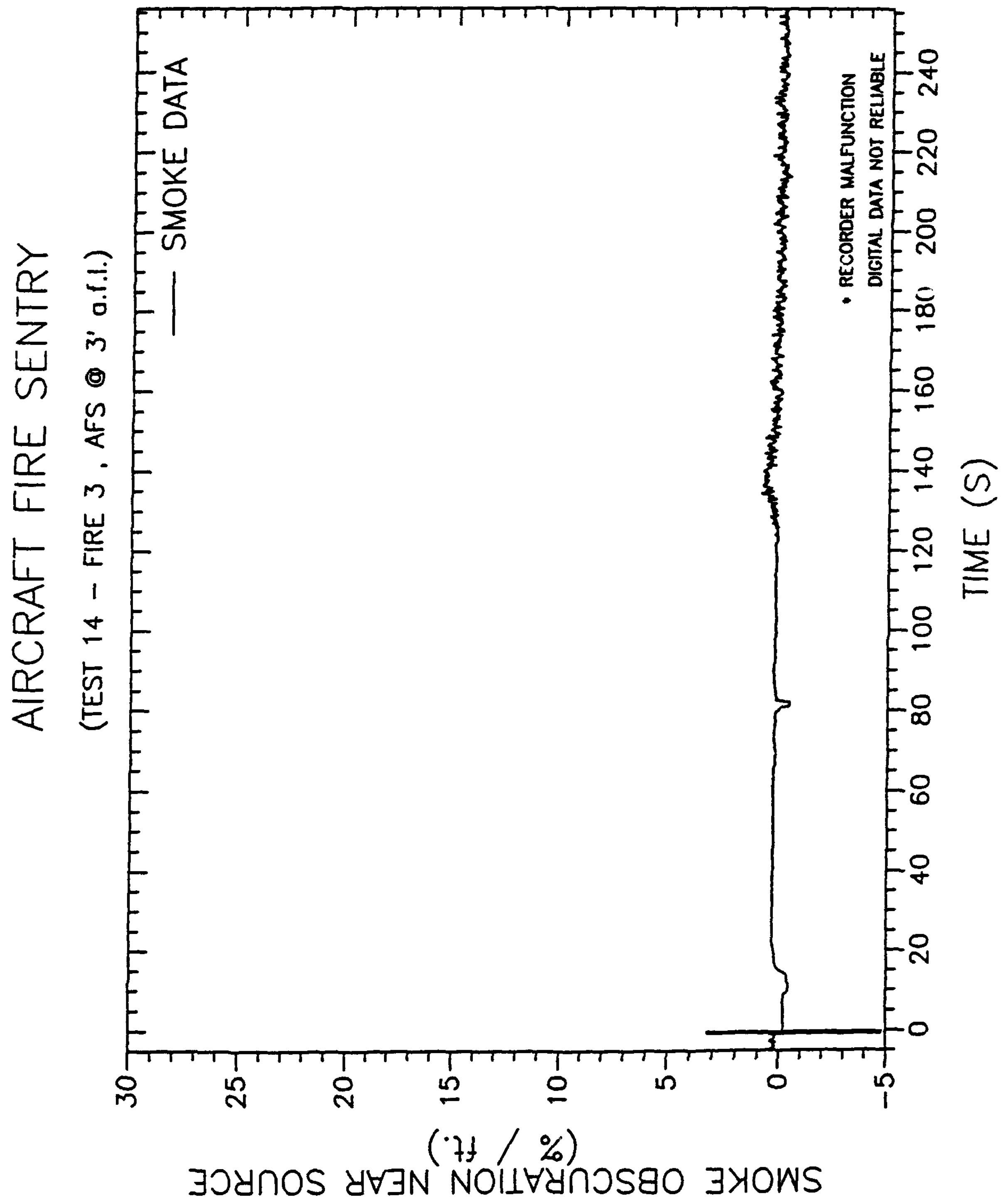

AIRCRAFT FIRE SENTRY
(TEST 13 - FIRE 2 , AFS @ 6' a.f.l.)
TEMP
TEMPERATURE RISE NEAR FIRE SOURCE (F)
480
440
400
360
320
280
240
200
160
120
80
40
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)

AIRCRAFT FIRE SENTRY

(TEST 14 – FIRE 3 , AFS @ 3' a.f.l.)

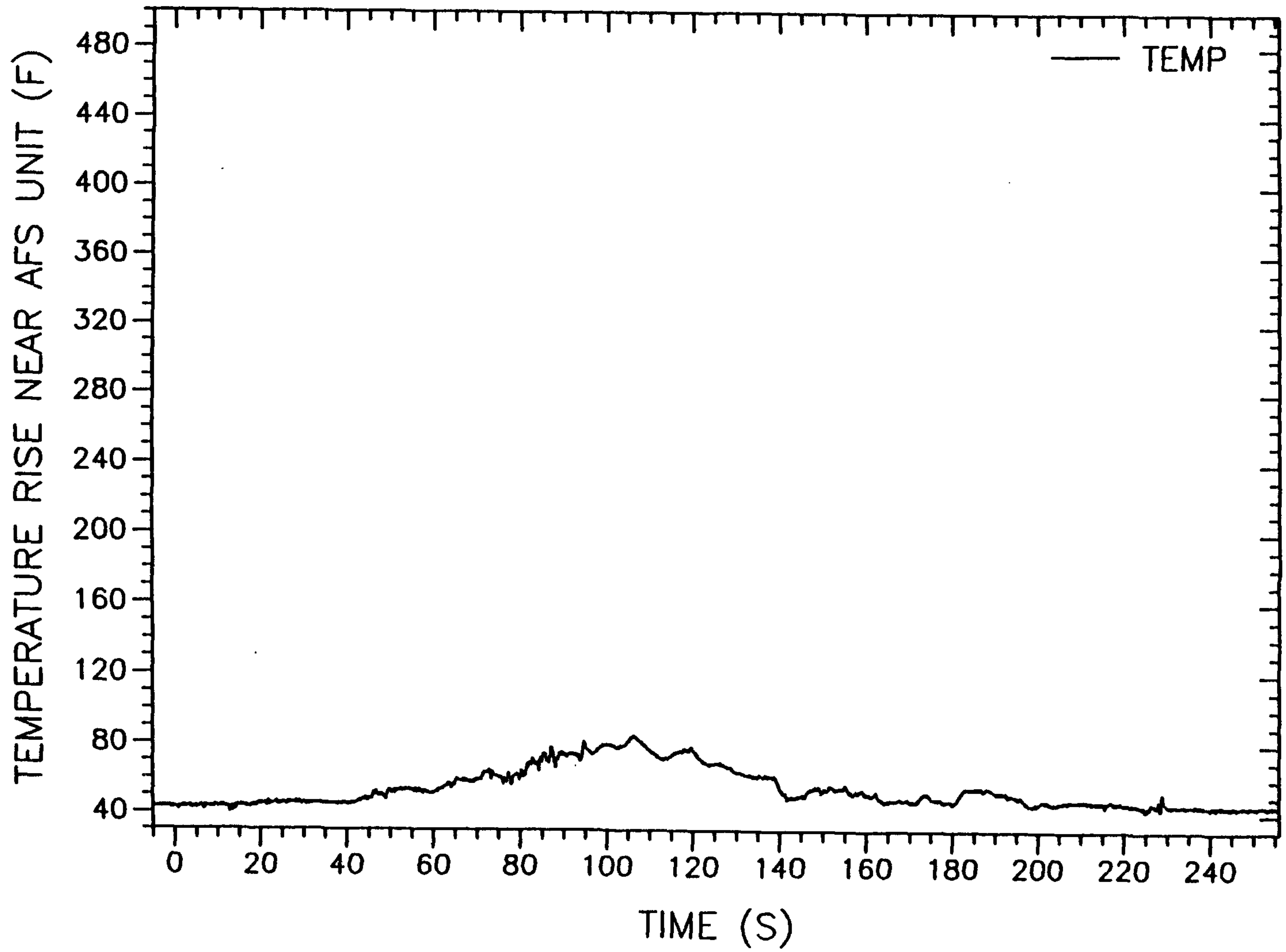



AIRCRAFT FIRE SENTRY
(TEST 14 - FIRE 3 , AFS @ 3' a.f.l.)
SMOKE DATA
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240
0
2
4
6
8
10
12
14
16
18
20


AIRCRAFT FIRE SENTRY
(TEST 14 – FIRE 3 , AFS @ 3' a.f.l.)
— SMOKE DATA
• RECORDER MALFUNCTION
DIGITAL DATA NOT RELIABLE
TIME (S)
SMOKE OBSCURATION NEAR SOURCE
(% / ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
30
25
20
15
10
5
0
–5

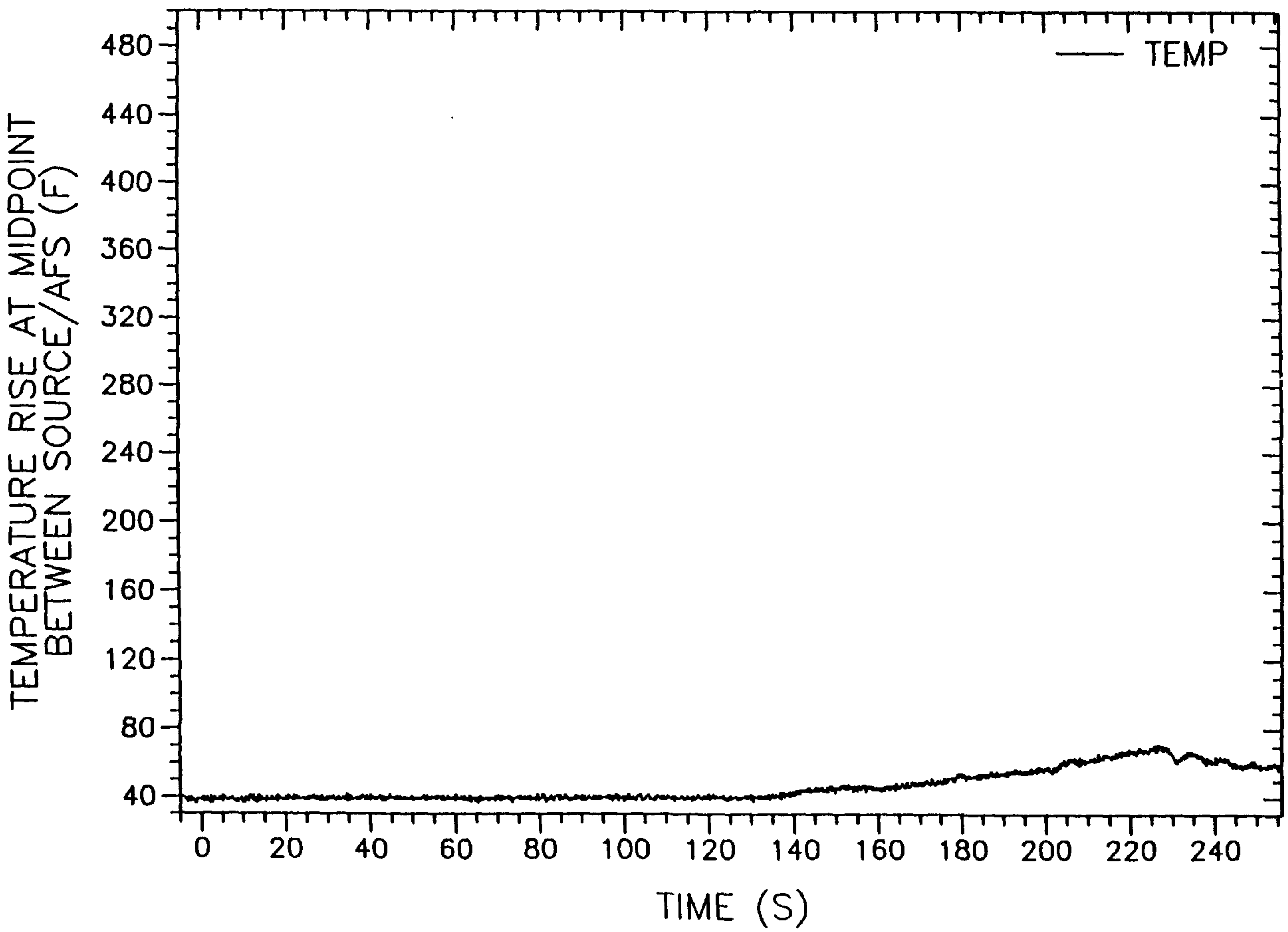
AIRCRAFT FIRE SENTRY

(TEST 14 – FIRE 3 , AFS @ 3' a.f.l.)



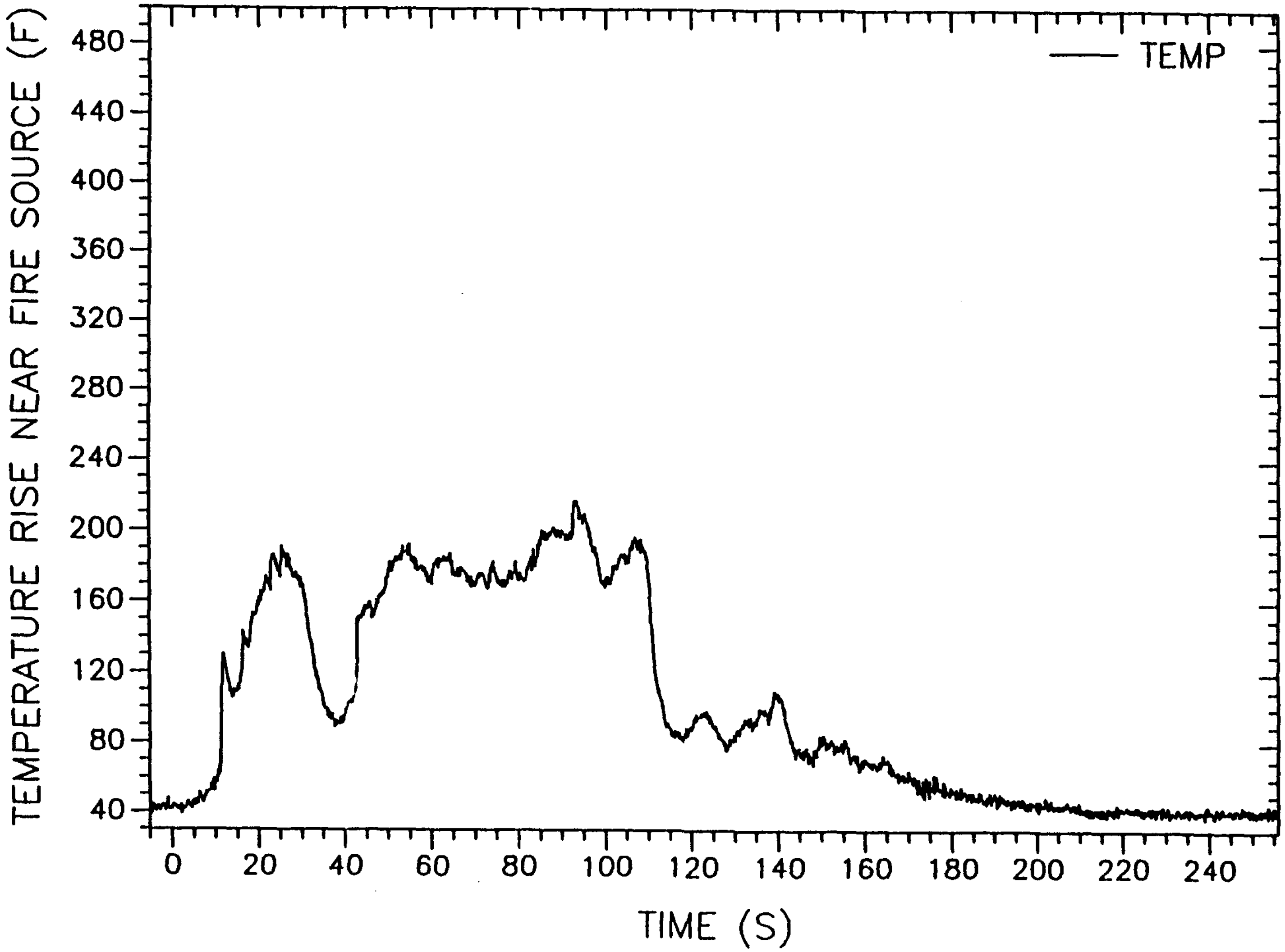
AIRCRAFT FIRE SENTRY

(TEST 14 – FIRE 3 , AFS @ 3' a.f.l.)



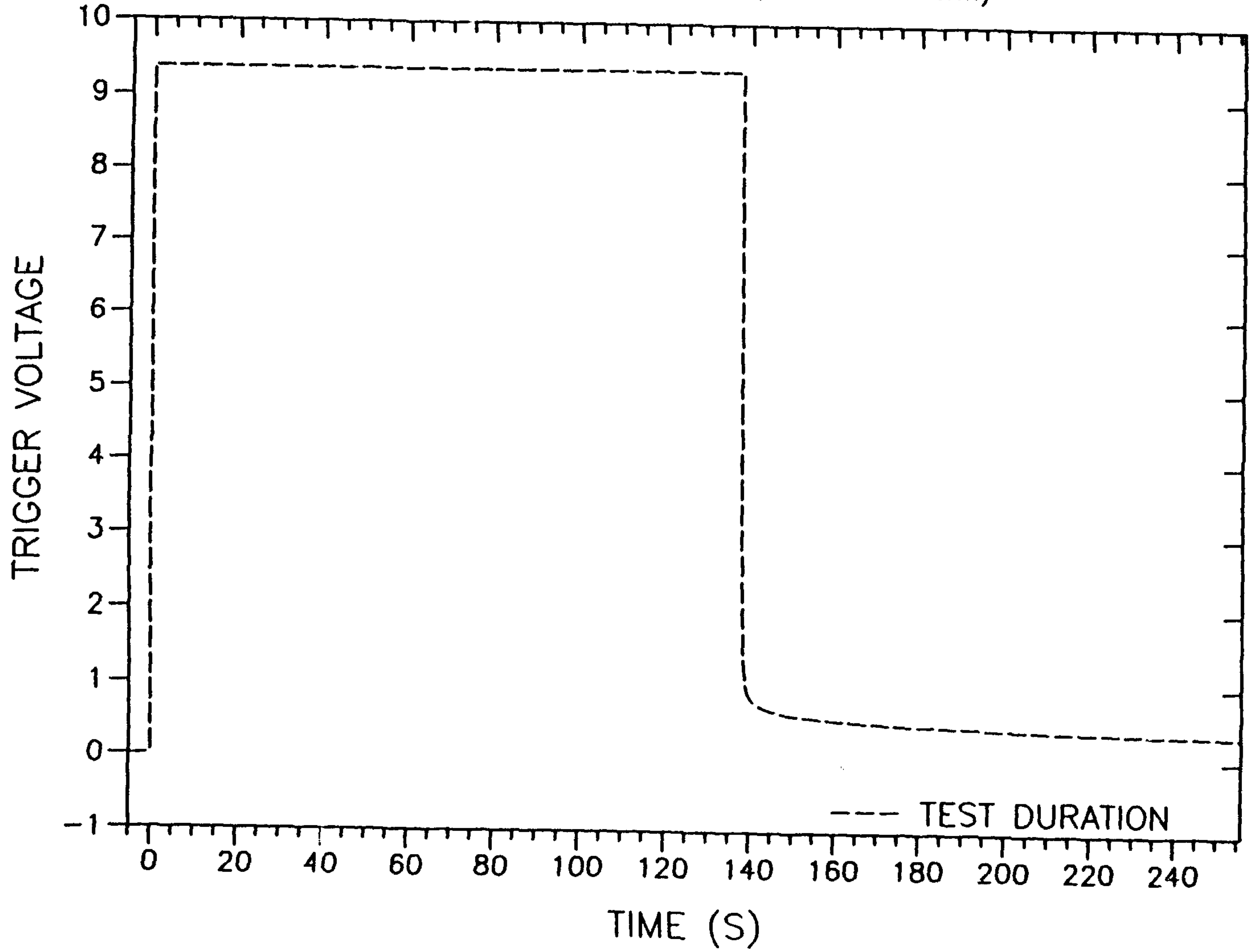
AIRCRAFT FIRE SENTRY

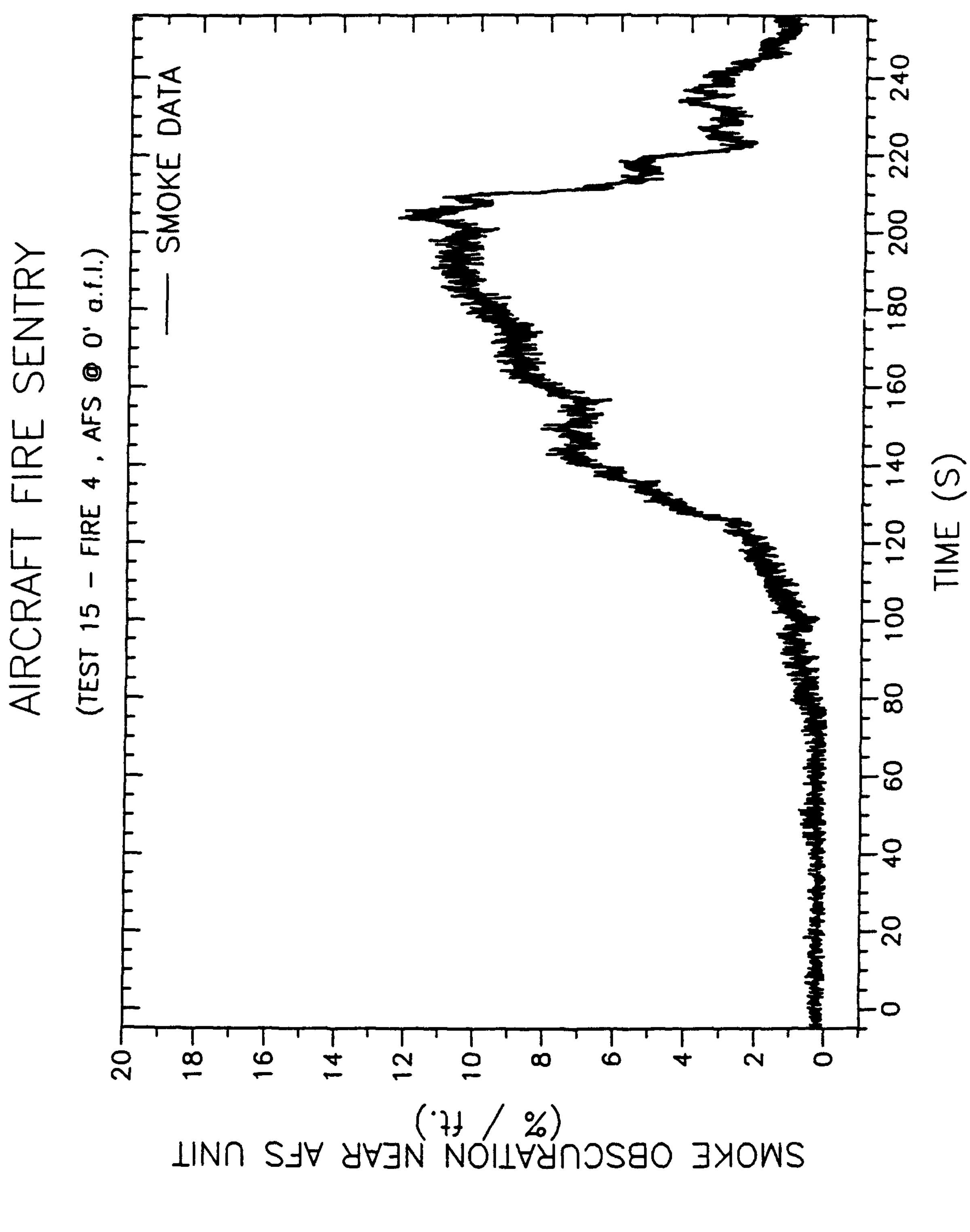
(TEST 14 – FIRE 3 , AFS @ 3' a.f.l.)

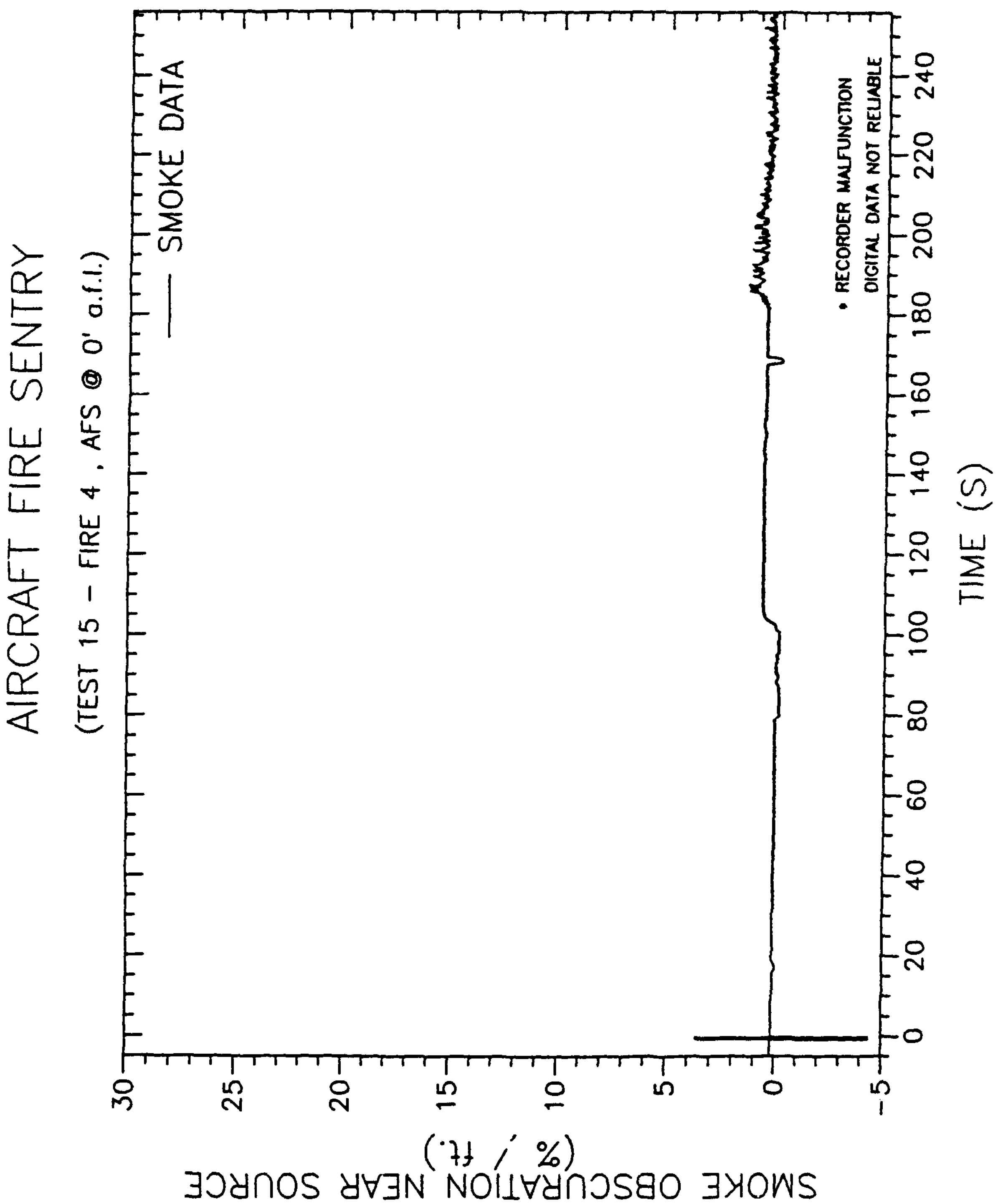


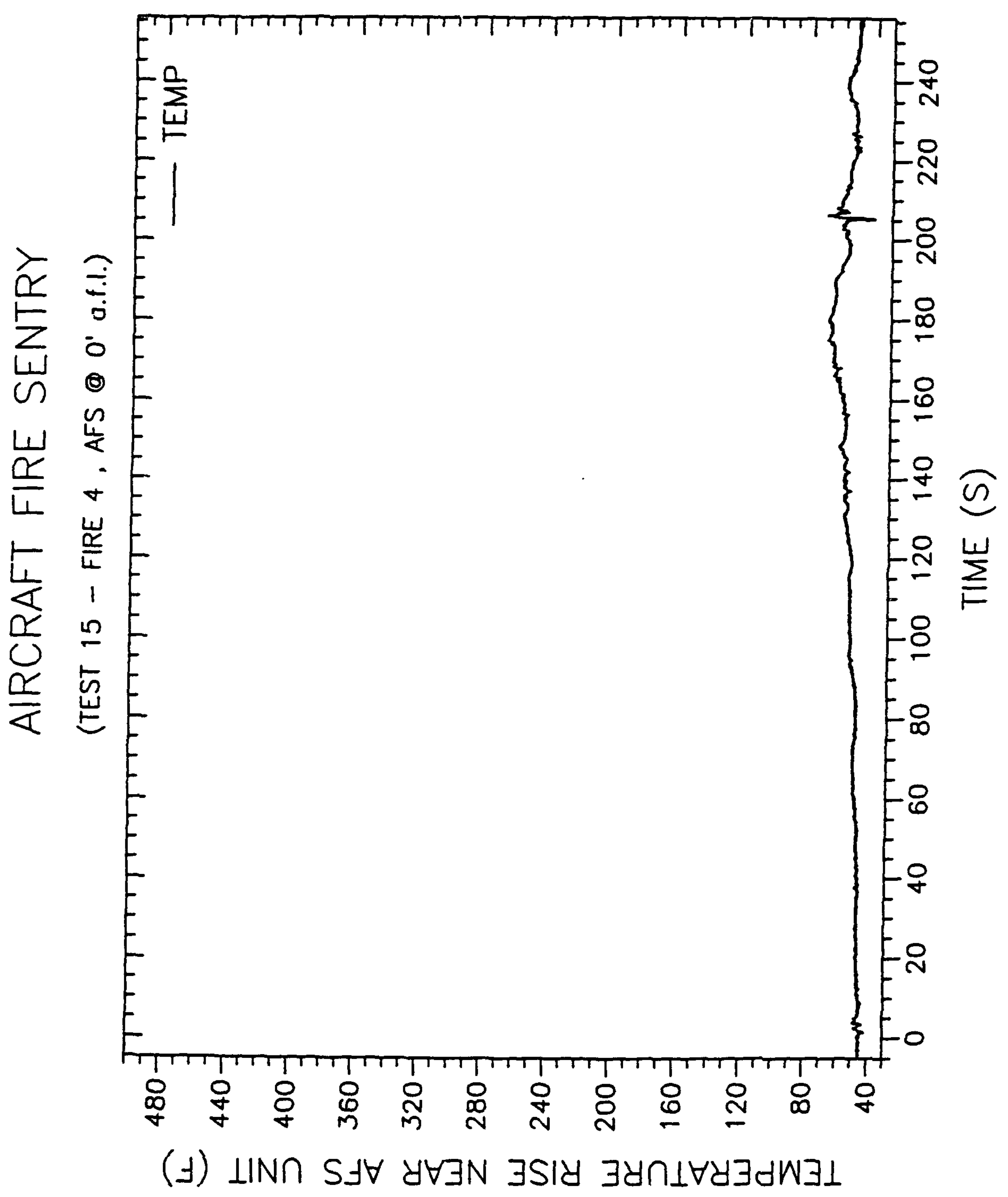
AIRCRAFT FIRE SENTRY

(TEST 15 – FIRE 4 , AFS @ 0' a.f.l.)



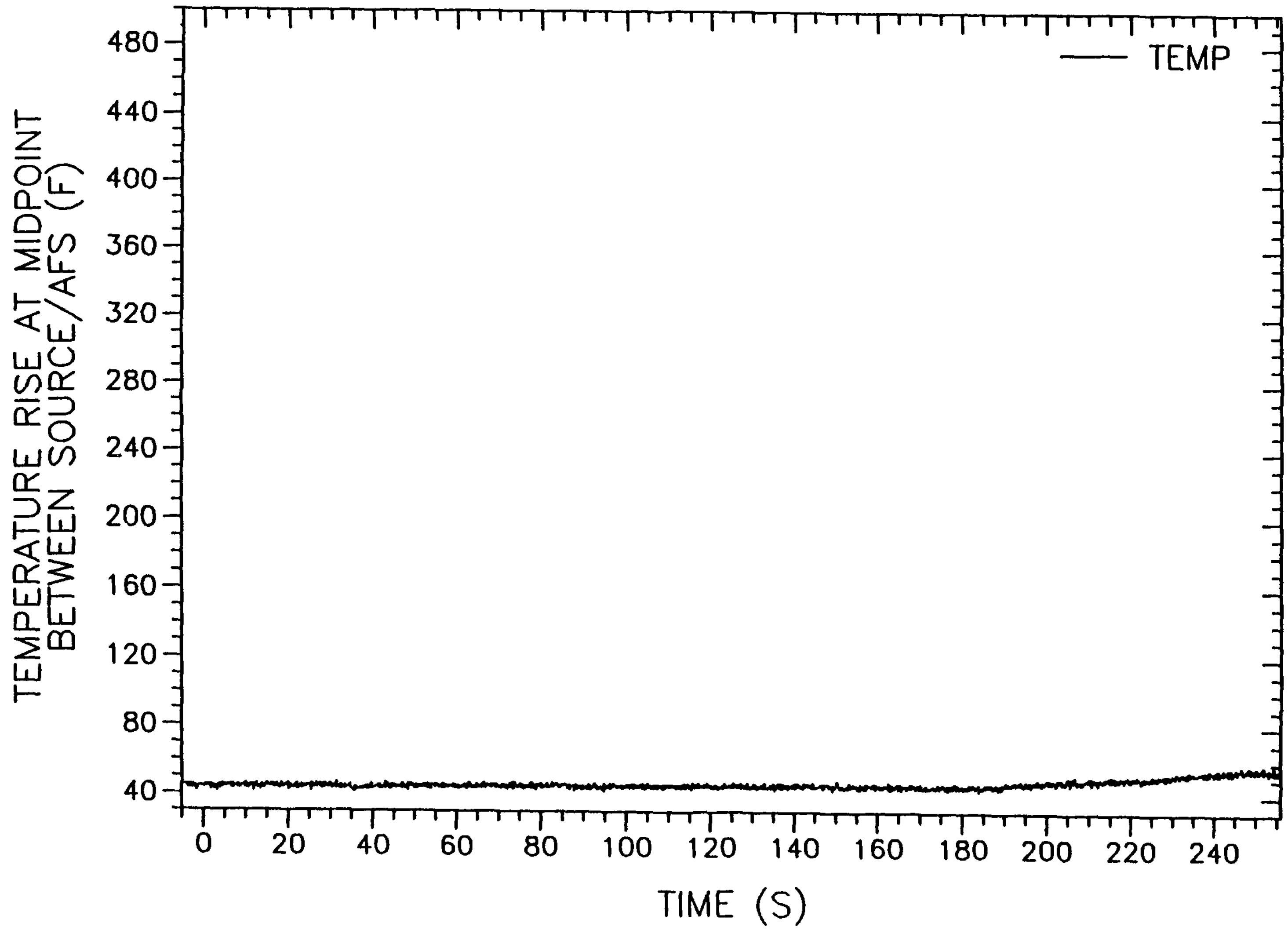

AIRCRAFT FIRE SENTRY
(TEST 15 - FIRE 4 , AFS @ 0' a.f.l.)
SMOKE DATA
SMOKE OBSCURATION NEAR AFS UNIT (% / ft.)
TIME (S)
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240

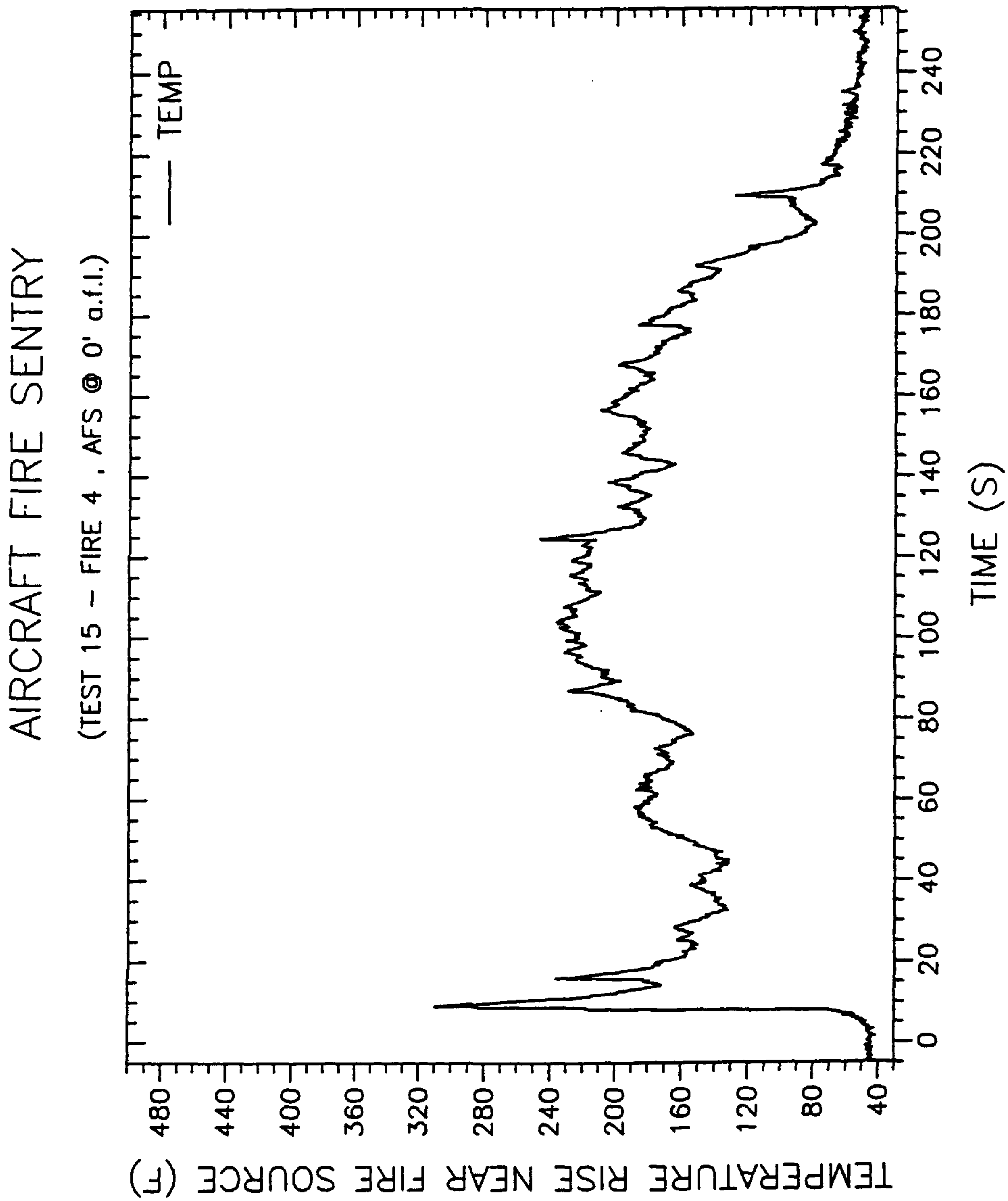

AIRCRAFT FIRE SENTRY
(TEST 15 - FIRE 4 , AFS @ 0' a.f.l.)
SMOKE DATA
• RECORDER MALFUNCTION
DIGITAL DATA NOT RELIABLE
TIME (S)
SMOKE OBSCURATION NEAR SOURCE (% / ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
30
25
20
15
10
5
0
-5


AIRCRAFT FIRE SENTRY
(TEST 15 – FIRE 4 , AFS @ 0' a.f.l.)
TEMP
TIME (S)
TEMPERATURE RISE NEAR AFS UNIT (F)
0
20
40
60
80
100
120
140
160
180
200
220
240
40
80
120
160
200
240
280
320
360
400
440
480

AIRCRAFT FIRE SENTRY

(TEST 15 – FIRE 4 , AFS @ 0' a.f.l.)



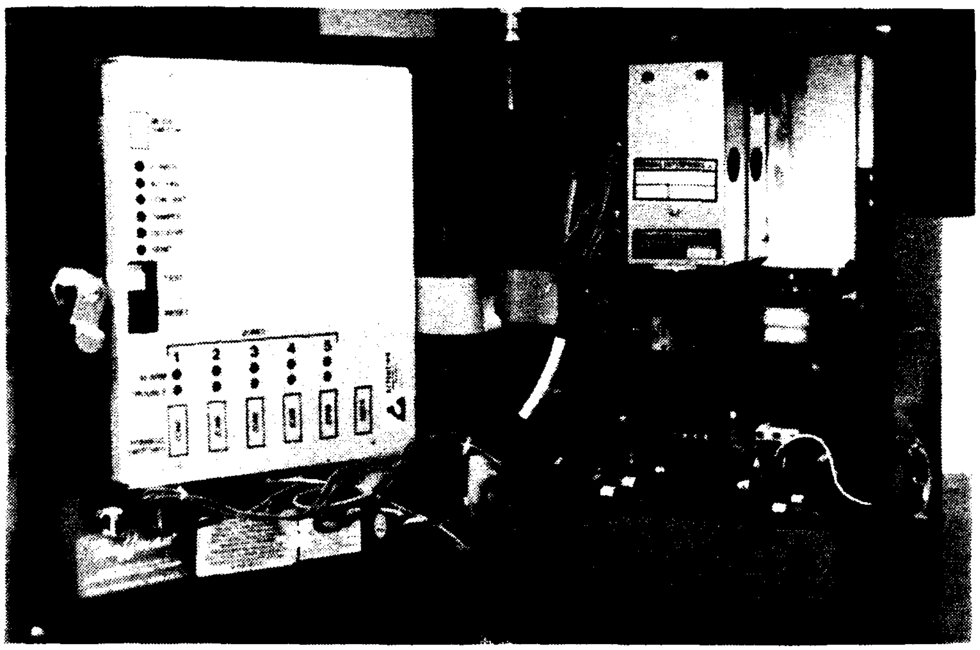

AIRCRAFT FIRE SENTRY
(TEST 15 - FIRE 4 , AFS @ 0' a.f.l.)
TEMP
TEMPERATURE RISE NEAR FIRE SOURCE (F)
480
440
400
360
320
280
240
200
160
120
80
40
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240

APPENDIX B

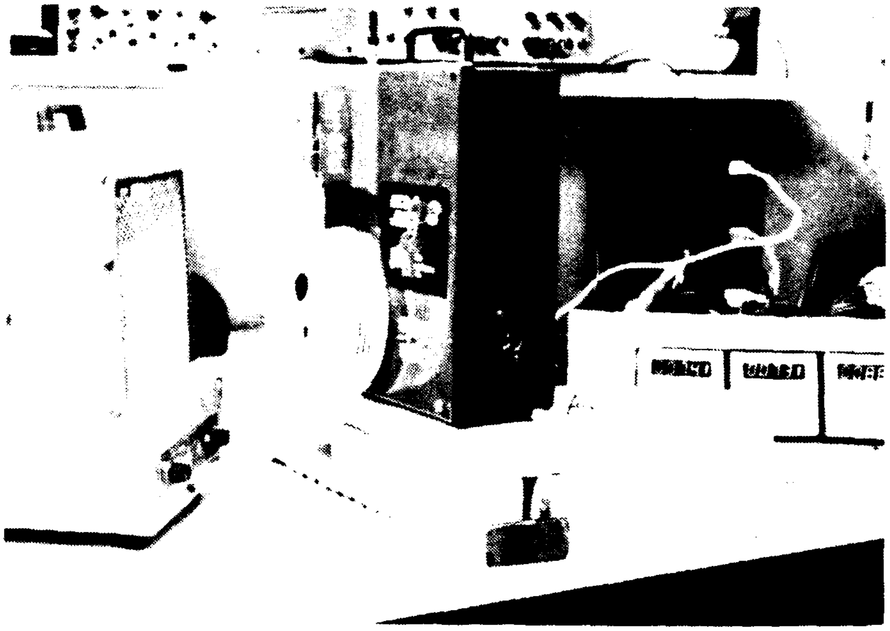
ANNEX D

Photodocumentation of Aircraft Fire Sentry hardware and selected test event equipment setups.

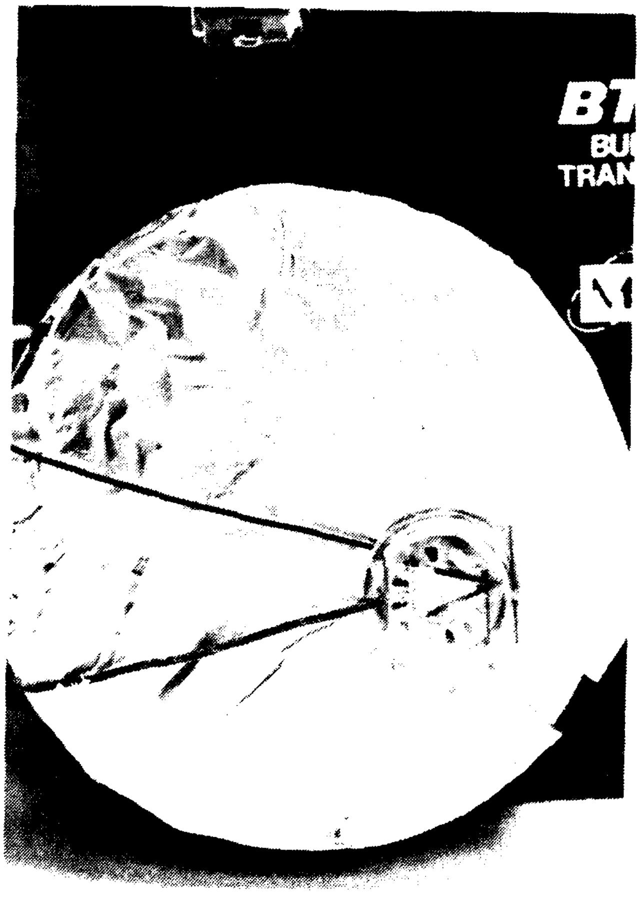
AFS Remote Tx/Rx (BT2-3)



Internal Components of BT2-3

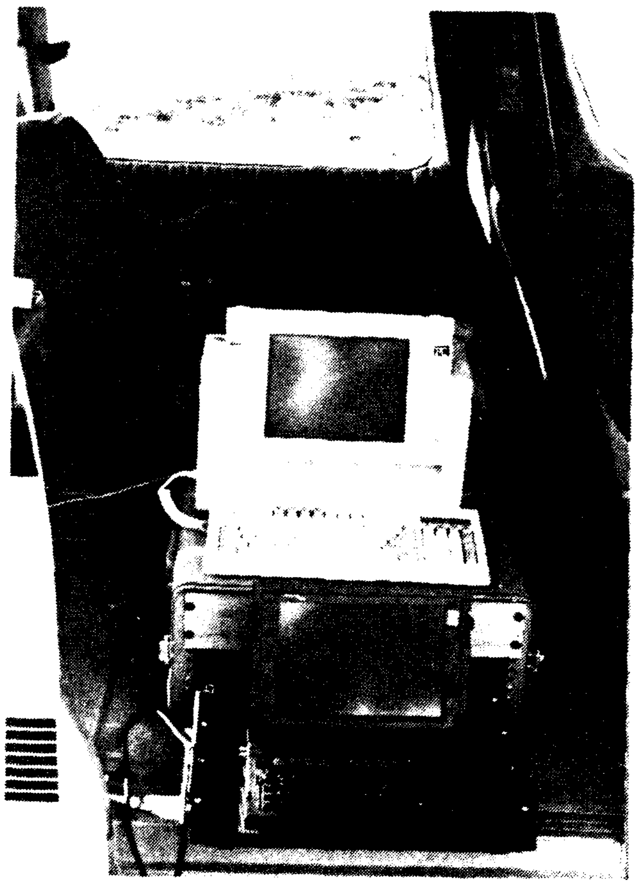


Apparatus for Heat Tests

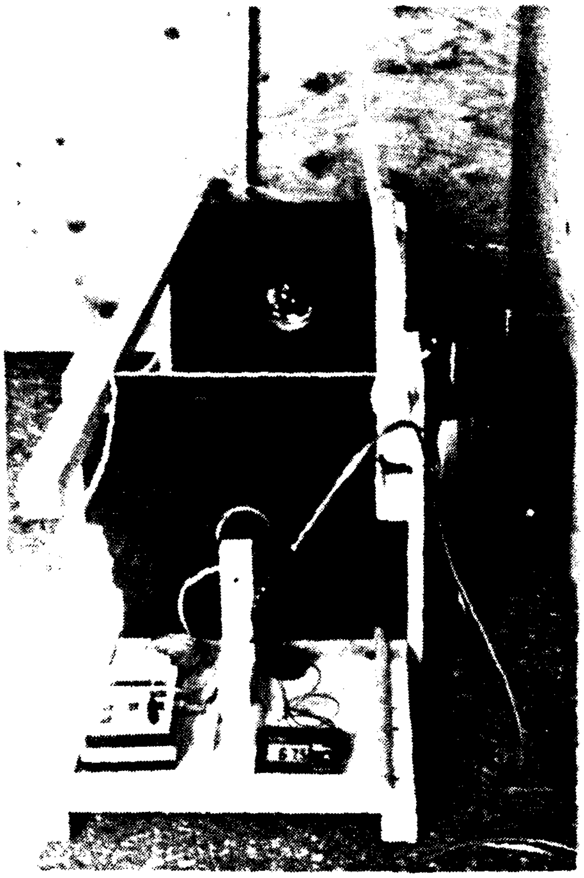


Thermocouple Installation and Heat Shield
Used During Heat Tests

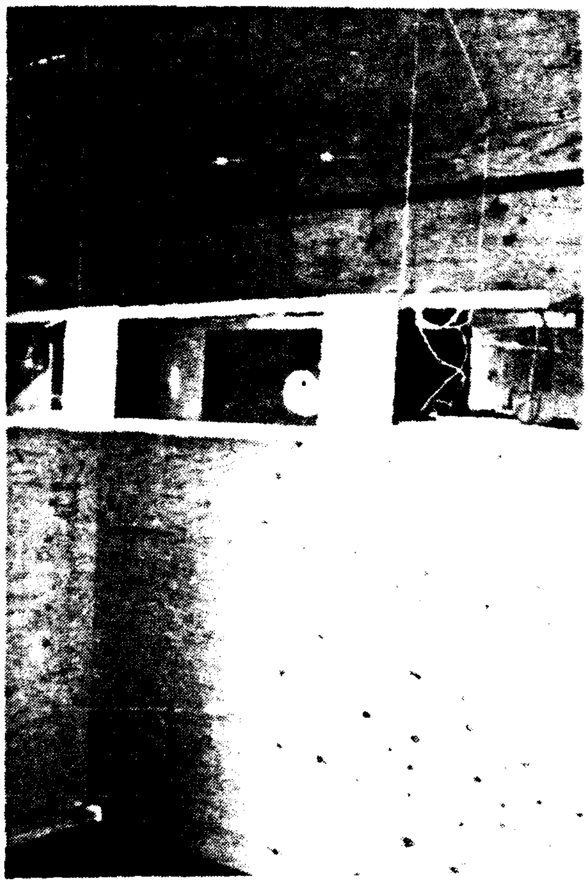
Instrumentation Van with Recording Equipment



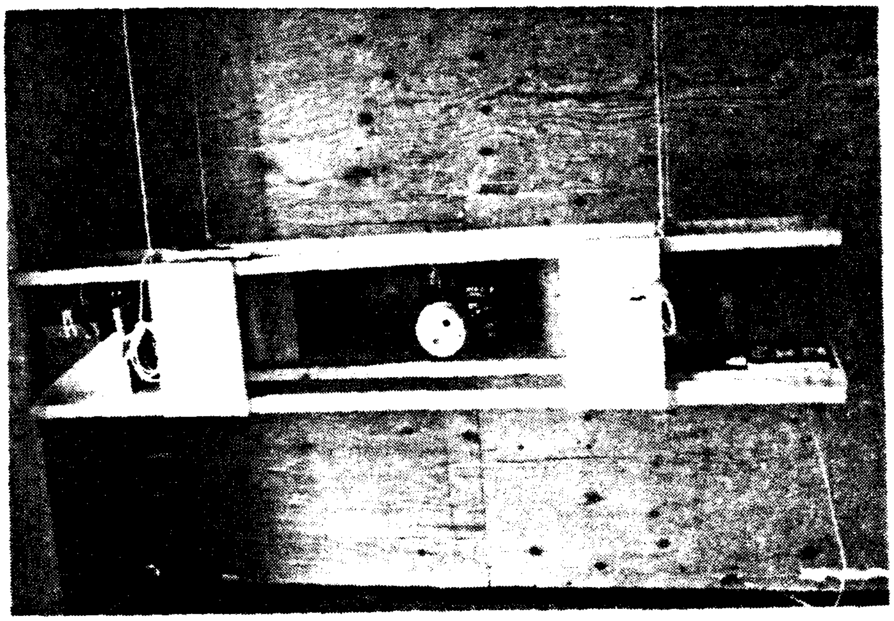
Portable 386 PC Computer and AFS Central Tx/Rx (D-500 Plus)



AFS Remote Unit Prior to
Test at Floor Level



AFS Remote Unit Prior to
Test at 6 Feet



AFS Remote Unit Prior to Test at 3 Feet

Smoke/Fire Source Bucket Location
(All Tests)

AFS Remote Unit Prior to
Test at 9.5 Feet

APPENDIX C

PROTOTYPE DEVELOPMENT, CONSTRUCTION, TESTING, AND EVALUATION

(The reverse of this page is blank.)

AIRCRAFT FIRE SENTRY

PROTOTYPE DEVELOPMENT, CONSTRUCTION, TESTING, AND EVALUATION

Task 3 Report

Prepared for:

Headquarters, Air Force Engineering Services Center,
Scientific and Engineering Technical Assistance (SETA)
Tyndall Air Force Base, Florida 32403

Contract Number F08635-88-C-0067
Supplemental Support Group Subtask (SSG) 3.14.1

Prepared by:

Applied Research Associates, Inc.
7114 W. Jefferson Avenue, Suite 305
Lakewood, Colorado 80235

Written by:

Robert Mugele

Peter T. Dzwilewski
Principal Investigator

Date: 25 September 1992

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

The Aircraft Fire Sentry (AFS) system is designed to automatically detect a fire in the cargo bay of large cargo aircraft, provide an audio and visual alarm locally, and remotely notify the nearest fire department. The basic design philosophy in developing the AFS was to use currently available commercial fire detection hardware and radio transmitters/receivers, and to package these components in a lightweight portable unit. The AFS is to be placed aboard a parked cargo aircraft and left to sense fire stimulus for up to 60 continuous hours in the self-powered mode.

The development of the AFS was done in two stages. In the first stage, a "breadboard" AFS was designed, built, and tested. This phase of the project was documented in the Task 2 Report. Following the evaluation of the "breadboard" AFS, the second stage began. The features of the prototype were developed, the prototype was constructed, tested, and evaluated. The stage two development is documented in this Task 3 Report.

In the report sections that follow, the prototype unit is described, the test series and test results are summarized, and an evaluation is made.

2.0 PROTOTYPE DESIGN DESCRIPTION

The prototype AFS unit is a self-powered, portable fire sensing and alarm reporting system (Figure C-1). The unit is carried on board and set up in the cargo bay of large aircraft. The set-up involves placing the wireless smoke detector(s) in the desired locations inside the aircraft, attaching the system antennas and cables to the unit, and hanging the strobe/siren assembly outside. One external switch powers up the AFS, and at this time it is actively sensing fire or smoke conditions and able to report an alarm to the base fire department over a preset radio frequency (RF).

The types of detectors on the prototype are smoke and flame. The smoke detector(s) are battery powered photoelectronic smoke alarms with a built-in wireless transmitter. The sensitivity of the detector is 3.1% smoke obscuration per foot $\pm$0.5%. The operating frequency is 303.875 Mhz. The transmitter will produce three-second coded RF transmissions every 30 seconds as long as an alarm condition exists. It also has an internal horn (85 dB at 10 ft). The detector is six inches in diameter and weighs 12 ounces. Two of these wireless smoke detectors are provided with the prototype AFS.

The other type of detector is a standard ultraviolet (UV) flame detector. This unit operates on 12 VDC and has a 32° cone of vision with respect to its placement inside the enclosure. There is only one of these flame detectors used on the prototype and it is situated so that it looks out the backside of the prototype box (Figure C-2). Normal response time is 3 seconds at 12 feet for a 12" diameter hydrocarbon fire. It should be noted at this time that this UV detector is intended to illustrate that the AFS has flame detection capabilities. It is envisioned that an actual AFS would have flame detection capabilities in four separate directions, and that more advanced technology, such as the Machine Vision system, which is currently under development, could possibly be used. The advantage of using some system like Machine Vision is that it provides state-of-the-art flame detection with a very low to zero false alarm performance. The system would be placed in the AFS such that it would look out all four sides and have virtually a 360° cone of vision.

The prototype's sensors (or detectors) differ from those of the previous breadboard small scale design AFS in three ways. First, there is no heat detection capability on the prototype. Task 2 testing on the small scale system indicated that heat levels were not rising high enough to trigger an alarm before another sensor (smoke) initiated an alarm. Therefore, it was concluded that heat sensors would generally be an added expense to the prototype configuration and not too useful. In addition, the heat sensor tested would alarm at an average of 176°F, while rated at 135°F. The second major difference is that the prototype has flame detection, while the previous design did not. This capability is seen as a must, and a perfect compliment to smoke detection for an effective well-balanced system. The third

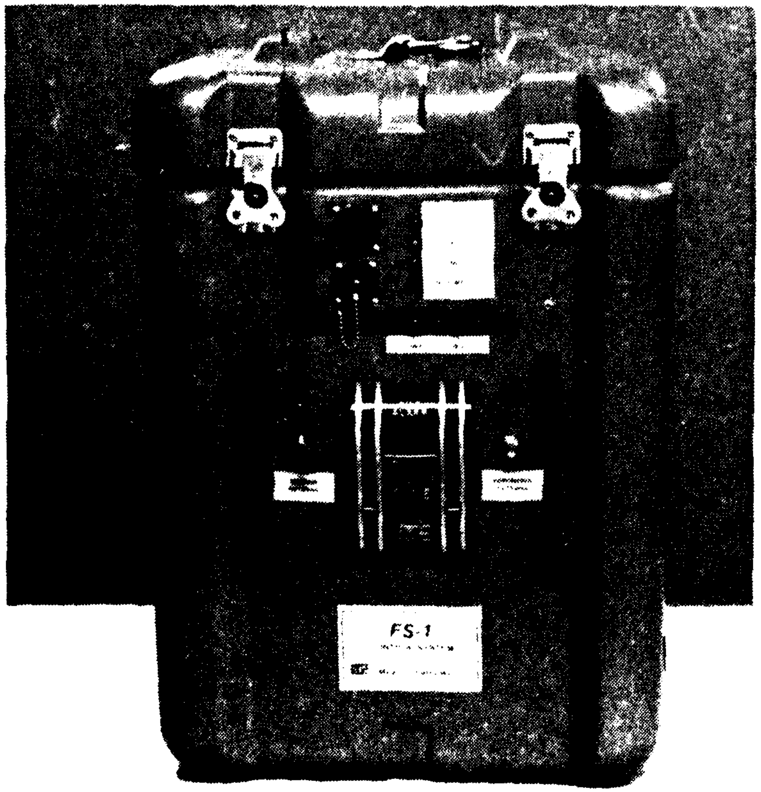


Figure C-1. Prototype Aircraft Fire Sentry Unit

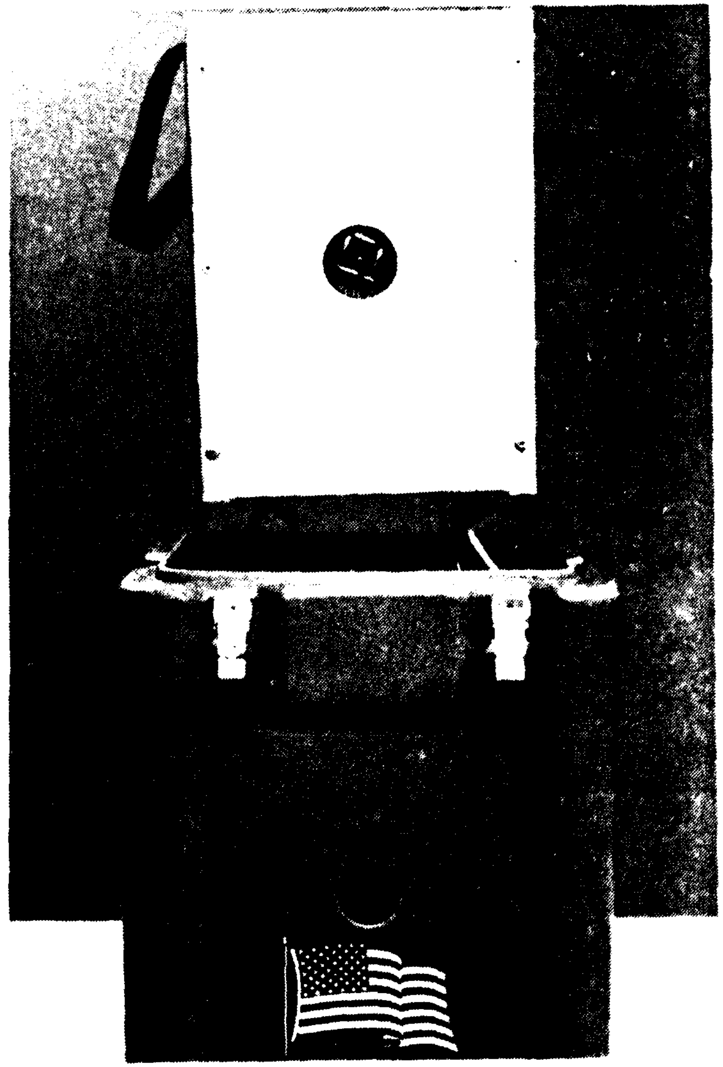


Figure C-2. Prototype AFS UV Sensor

difference is that the smoke detector(s) for the prototype are remote (that is, not hardwired or attached) to the AFS enclosure which contains the transmitters, electronics, etc. This is seen as an advantage in that the prototype unit (with flame detection) could be placed at a suitable location mid-fuselage while the wireless smoke detector(s) can be placed at multiple locations for quicker, more efficient response to a smoke source. Both the prototype and small scale AFS concepts have included a manual pull station to enable personnel to initiate an alarm at anytime.

Fundamental to the success of the AFS is the understanding of the communication network on which it operates. The prototype AFS assembly is essentially a remote transmitting and receiving station of radio frequency signals.

At the base fire department of the majority of U.S. air bases is a central transmitting/receiving station which is being monitored by personnel for hazards anywhere on base. As soon as an AFS detector triggers, an alarm signal is sent to the AFS unit and an alarm condition occurs at that location. As the electronics in the AFS receive the alarm from the detector, another signal is then generated which notifies the base fire department of the type and location of the problem. The messages received at the fire station can be what went into alarm (smoke detector, manual pull station, etc.) and where to send help (tail number of plane, location on the ramp, etc.). The result of a properly operating and set up AFS system is efficient, automatic fire detection and notification.

The hardware used for the Tx/Rx communications between the AFS prototype and the central station is the Monaco Enterprises, Inc. BT2-3 Building Transceiver and the D-500 Plus Advanced Wireless Information Management Alarm Receiving and Reporting System, respectively. The BT2-3 has five zones, each being responsible for receiving the input of one sensor. The BT2-3 scans these zones for alarm conditions twice per second. On the prototype, Zone 1 is for system trouble or tamper, Zone 2 monitors the manual pull station, Zone 3 monitors the UV flame detector, and Zones 4 and 5 are for the two smoke detectors. The BT2-3 uses a rechargeable 12 VDC battery for power. At the central station, the D-500 Plus is AC or DC powered and computer based. Its software is specifically designed to monitor the remote BT2-3 units. Although the D-500 Plus is integral to the whole AFS concept, the focus of AFS prototype design efforts is on developing an efficient, portable remote unit. Operating radio frequency for the AFS is 138.925 Mhz.

The majority of components are housed in a high-impact plastic, environmentally sealed enclosure approximately 14" wide x 14" long x 20" high. Total weight of the assembly is 39 pounds. It has three handles, one on each side, and one on the top for carrying purposes. On the front of the unit are the power and system reset switches along with four LED's indicating power on, low battery, trouble and transmit. In the prototype, only the power on LED is functional. The

remaining three were never wired into the system before shipping. Four connectors are provided on the front. Four different types of quick connects prevent a wrong hook up of the external components, which are the sensor antenna, reporting antenna, the combination siren/strobe and a spare. Also on the front of the box is the manual pull station. Other external features include a place to plug in the AC power/battery recharging cord on the side of the unit and a small 1.75" diameter window on the back for the UV sensor.

The lid is held on by four steel latches. Removing the lid allows access to a 9" wide x 9.5" long x 4" high aluminum storage tray, which contains the AFS system peripherals. These include the smoke detector, the two system antennas, the siren/strobe and its cable (Figure C-3).

Below the storage tray are all the electronics mounted on telescoping equipment rack. When extended, the overall height of the AFS is 31.5 inches, which allows easy access to the equipment. The major electronic components inside are the BT2-3 circuit board, transmitter/receiver modules, interface/relay assembly, UV flame detector, wireless sensor receiving unit and the 12 volt 6.5 AH rechargeable battery (Figure C-4).

Monaco Enterprises, Inc., of Spokane, Washington, did the layout and assembly of the prototype AFS.

Figure C-3. Prototype AFS Storage Compartment and Recharge Cord

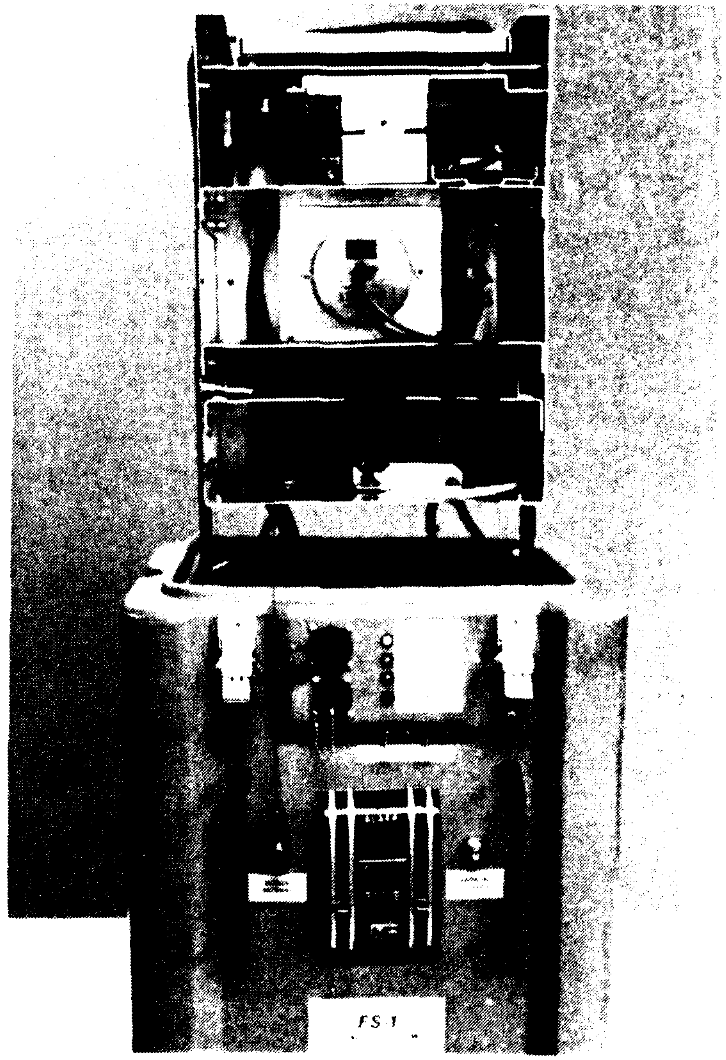


Figure C-4. Prototype AFS Equipment Rack in Extended Position

3.0 TEST SERIES

3.0.1 General Test Description

The Task 3 test series was designed to test the functional aspects of the final prototype assembly. Specific tests were conducted to evaluate the performance in five key areas, which are: 1) RF transmission qualities; 2) stand-by duration of the system; 3) proper hardware operation (Manual Pull Station); 4) fire stimulus sensitivity and reporting; and, 5) distance testing of the wireless smoke detectors.

The testing was carried out at three locations. Field testing of the AFS RF transmission qualities in actual cargo aircraft was done at Fairchild AFB near Spokane, Washington on May 21, 1992 and again on June 12, 1992. Live fire testing, including distance testing of the smoke detectors, was done at Applied Research Associates' remote test site (30 miles east of Denver, Colorado) between July 21 and August 5, 1992. The remaining tests, duration and manual pull were done at ARA's Lakewood, Colorado offices during the same time period.

Outlined in Annex A of this report are the step-by-step procedures followed for each type of test. It covers all of the tests with the exception of the work done at Fairchild AFB in which experienced Monaco personnel followed informal but thorough procedures to verify proper RF transmissions.

3.0.2 Instrumentation

To measure the performance of the AFS prototype and the environment of the live fires, various instruments were used and, where possible, the outputs digitally recorded.

The instrumentation used included:

smoke obscuration (smoke density) detector
thermocouples
voltmeters
duration trigger box
stopwatch
digital recorders
video
35 mm photography
portable radio frequency scanner
radio frequency spectrum analyzer

For the Smoke and Live Fire tests, smoke density was measured and converted into percentage obscuration per foot. This is the standard to indicate

sensitivity of commercial smoke detectors (reference: UL 268 "Smoke Detectors for Fire Protective Signaling Systems"). The main components of a smoke obscuration detector are a lamp with a power supply and a photocell with signal conditioning. These components are mounted to a structure which separates the lamp and photocell by exactly five feet. During operation, with the lamp on, an amperage is created in the photocell and converted to an analog voltage output by the signal conditioner (Figures C-5 and C-6).

As smoke passes between the lamp and photocell, the amperage created by the photocell decreases. At any distance, the percentage obscuration per foot can be calculated by:

$$S.O. = \left[1-\left(\frac{V_F}{V_I}\right)^{\frac{1}{D}}\right]100$$

where: *S.O. is percent obscuration per foot,*
V_F is voltage reading with smoke,
V_I is voltage reading in clean air,
D is distance between lamp and photocell.

Smoke obscuration was measured near the prototype's remote smoke detector for all of the live fire/smoke tests. Centerline of measurement for the obscuration detector was approximately 12 inches from the AFS smoke detector. The way the system is set up, the recorded output is the average density over five feet.

Fast response thermocouples were used to monitor temperature during the Live Fire tests. The current generated by the thermocouple was conditioned by a digital pyrometer. The pyrometer used the thermocouple output, referenced it to $32^{o}F$, linearized and amplified the signal, then output a 0 to 5 volt DC signal. The pyrometer also has a 4 digit display to observe the temperature in real time.

Temperatures were recorded at three locations. TEMP1 was near the fire source to give an indication as to the approximate heat produced (Figure C-7). TEMP2 was measured at the AFS prototype enclosure, which houses the transmitters. The AFS was always located on the floor directly across the room from the fire and directly below the remote wireless smoke detector. TEMP3 was measured near the remote smoke detector (Figure C-8). This was valuable information as to whether or not the temperature reached heat sensor triggering levels before the smoke alarm went off. There was no heat sensor on the AFS prototype.

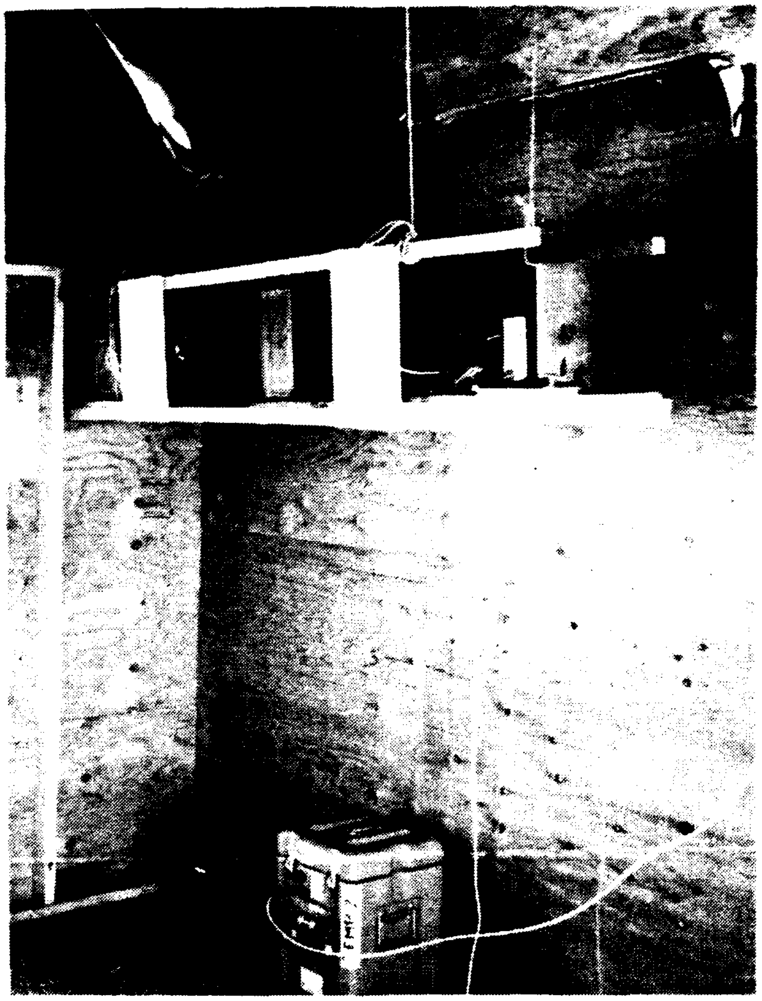


Figure C-5. Smoke Obscuration Detector Installed at 6 ft. Height in Test Structure

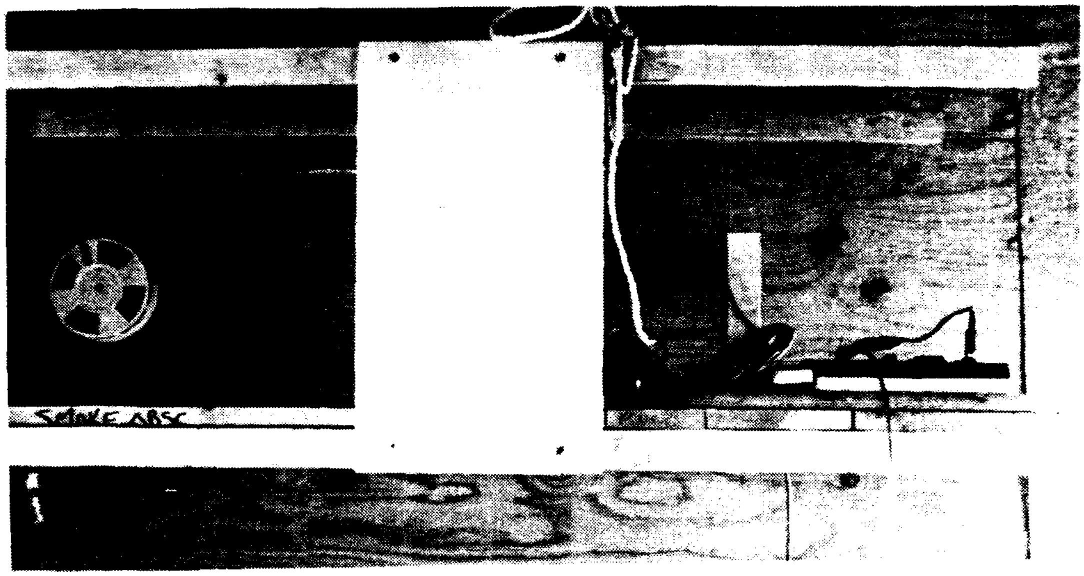


Figure C-6. AFS Smoke Detector and Smoke Obscuration Photocell

Figure C-7. Fire Source Pans and TEMP1 Location

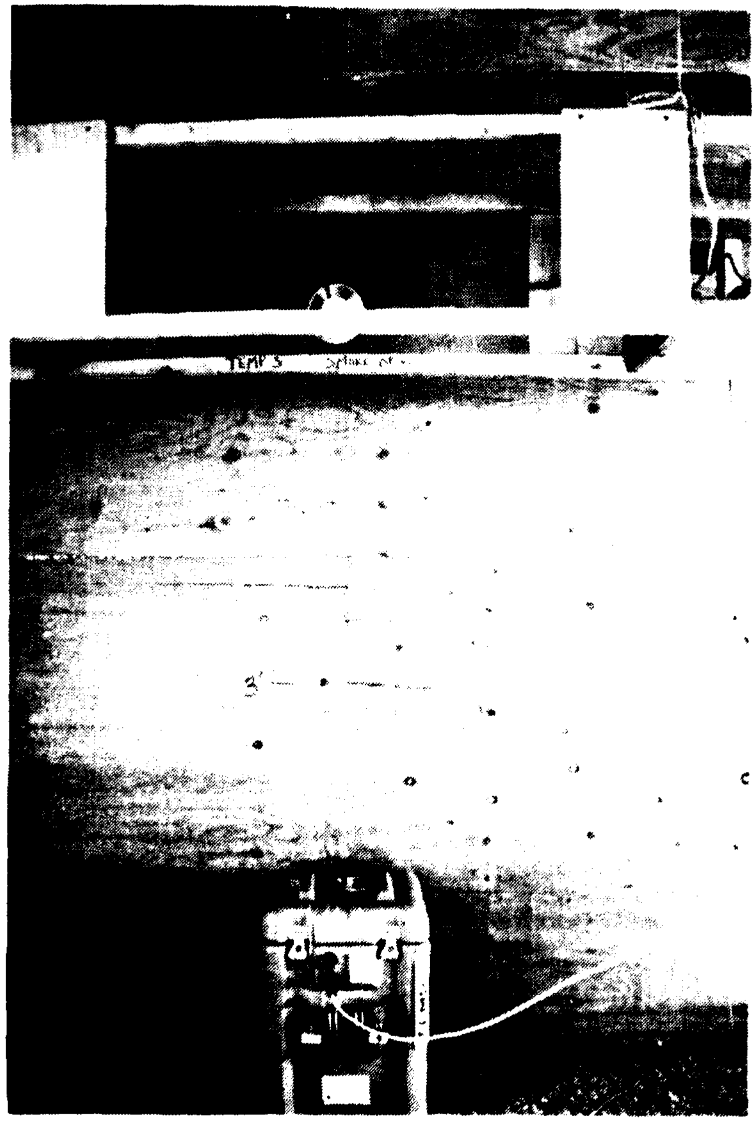


Figure C-8. Typical AFS and Smoke Detector Locations, and TEMP2 and TEMP3 Locations

Time reference for the Smoke and Live Fire tests was generated by a hand-held, 9-volt trigger box. As the smoke began or the fire set, the box was manually activated. This created a time reference for the recorders and also initiated recording of smoke obscuration and temperature signals. When the alarm was generated by the AFS unit, the trigger was deactivated, which sent another time reference signal to the recorders. A hand-held stopwatch was used as a back-up and during manual and heat testing.

Recording of data during the Smoke and Live Fire tests was achieved by stand-alone Digistar II digital recorders (Figure C-9). Manually monitoring voltmeters and the digital pyrometers, and documenting values at critical times was also performed (Figure C-10).

Photodocumentation of the live tests was accomplished with a color VHS video camera and a 35 mm SLR camera.

During this and the previous Task 2 test series, intermittent trouble was encountered with the D-500 Plus central transmitting/receiving station on loan to us from Tyndall AFB. The central Tx/Rx is the ultimate receiver of alarm messages from the AFS prototype and was being used to verify such transmissions. It is believed, however, that the unit had a faulty receiving module and would perform intermittently. As a backup, a portable radio scanner preset to 138.925 Mhz was used to pick up alarm signals in the event the central Tx/Rx did not.

During the second field test at Fairchild AFB, a Radio Frequency Spectrum Analyzer was used to measure transmitted signal strength between the remote AFS prototype (on the aircraft) and the central Tx/Rx unit (located at the base fire department).

3.1 TRANSMISSION TESTING

3.1.1 Test Description

As stated earlier, the radio frequency transmission testing was conducted at Fairchild AFB. The purpose of these tests was to deploy the system on an actual cargo aircraft and verify that the AFS system can operate as expected when installed. The tests were conducted over two days (non-consecutive). The second day was to test modifications and improvements as result of day one.

The layout was essentially the same for both days. The AFS prototype was brought onboard a KC-135 tanker aircraft parked approximately 1.1 miles from the base fire department, which is also the location of the central Tx/Rx.

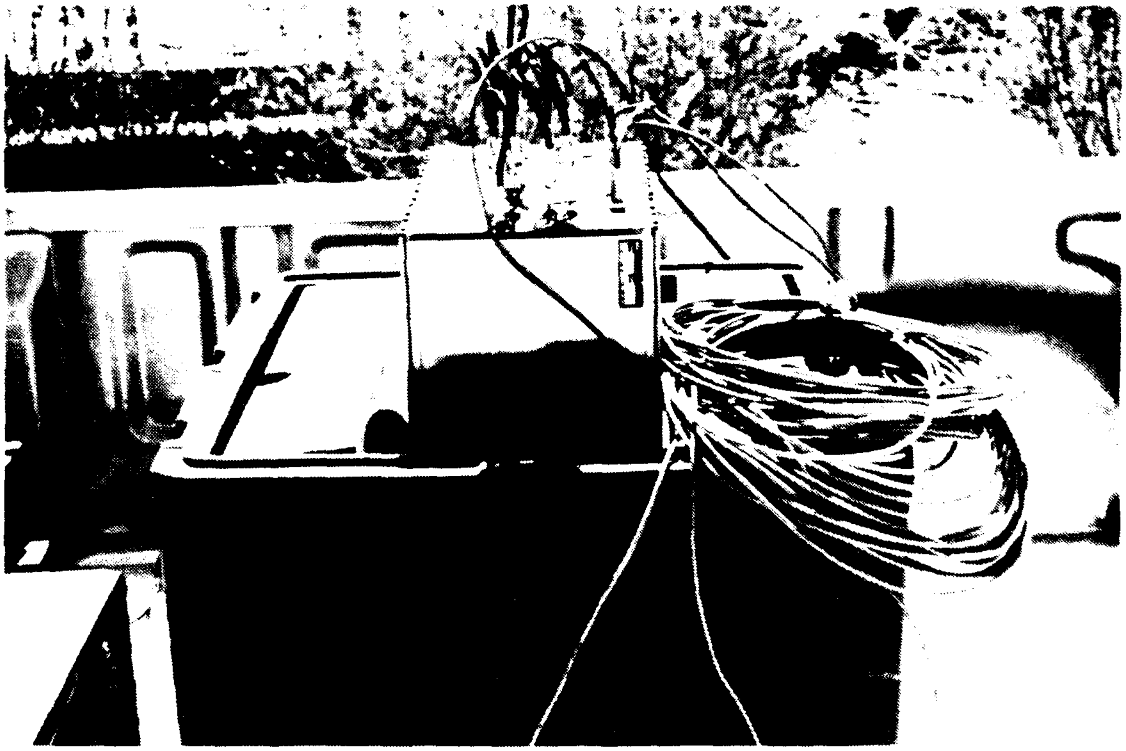


Figure C-9. Digistar II Digital Data Recorders

Figure C-10. Live Fire Testing Instrumentation

With the exception of the very first test, the prototype AFS was always inside the aircraft. Alarm signals were generated by both activating the manual pull station and pressing the test button on the wireless smoke detectors. Alarm messages received were verified at the fire department by walkie-talkie. From test to test, the locations of the AFS and smoke detector changed with respect to each other inside the aircraft. Twice the smoke detector was even brought outside the aircraft to see if it would trigger an alarm signal at the AFS.

3.1.2 Transmission Testing Results

Field Test #1, May 21, 1992

The first test was conducted at the parked location and just outside of the aircraft. The normal system antenna for the BT2-3 was assembled and hooked up to the AFS. This antenna is a 5/8 wave omnidirectional antenna with ground plane. Although not heavy, the antenna is large and cumbersome. Alarm messages were sent, and received at the fire department.

The equipment was then brought on board through the normal crew access hatch and set up. The siren/strobe was allowed to hang down through the access hatch to the outside of the aircraft. Tests were conducted with the AFS in the cockpit and the triggering smoke detector at mid and aft cargo bay. Alarm messages were correctly received at the fire department.

With the AFS and antenna moved from the cockpit to the forward end of the cargo bay, test buttons were pushed on the detectors at mid and aft cargo bay, and alarm messages were received at the fire department.

For the next two tests, the AFS remained in the forward cargo bay, and a smoke detector was brought outside and activated once near the nose of the plane and once near the tail. Both times, alarm messages were received at the fire department. After resetting the system, the manual pull handle was activated with successful results.

For the final test, the antenna was relocated to mid-cargo bay, putting the most obstruction (another aircraft) between the antenna and the fire department. Alarm signals were generated and received at the fire department.

Successful RF transmissions for each test have established that the AFS is a valid concept. The siren is sufficiently loud, but the strobe can be somewhat difficult to recognize in the daytime. The prototype unit is somewhat heavy and awkward to bring on board with only the side handles. A third handle was placed on the top for ease of handling as a result. The standard omnidirectional antenna is a multi-piece assembly that is inconvenient and

impractical to deploy in the field. A 40-inch collapsible antenna has been chosen as a suitable replacement.

Field Test #2, June 12, 1992

Since the first field test proved the system valid, the purpose of the second test was to verify the ability of the AFS to transmit effectively with the replacement collapsible antenna. For this test, a radio frequency spectrum analyzer was connected to the antenna at the central Tx/Rx station to measure incoming signal strength from the AFS.

The AFS was deployed in another KC-135 aircraft. The collapsible antenna was extended fully and placed mid-cargo bay. Alarm signals were generated by the wireless smoke detector and manual pull station, and proper alarm messages were received at the fire department. The BT2-3 transceiver (in the AFS) was then interrogated for its status by the central station and the replies were received.

Finally, the AFS was configured to send a continuous transmission, and the central station configured for the analyzer to measure signal strength. Results of this test show -95 dBm measured at the fire department's location. The minimum signal strength required to properly decode a radio message is -107 dBm. This leaves a small margin to allow for fade due to atmospheric conditions and other variables.

The handle added to the top of the unit and the collapsible antenna were successful modifications which simplified deployment. It is now possible for a single person to carry the AFS up the crew ladder into the aircraft. There was no significant drop in antenna efficiency by switching to the collapsible one.

3.2 60 HOUR DURATION TESTING

3.2.1 Test Description

When deployed in the field, the AFS will always be operating under its own internal battery power. The objective of this test is to satisfy the requirement that stand-alone operation of at least 60 continuous hours is possible without needing to recharge the battery.

These tests were carried out at the ARA offices. Prior to each test, the batteries in the AFS had received a full AC recharge and were verified at 12+ VDC by a digital voltmeter. A portable radio frequency scanner was used as the receiver of test signals generated by the AFS, as the D-500 Plus central station was out of service. To begin these tests, date, time, and battery voltage were noted and then

alarm signals generated (usually by the manual pull station) to verify proper RF transmission. The unit was then left alone with the power on for the duration of the test.

3.2.2 60-Hour Duration Test Results

The first test: Test Plan #1, July 31, 1992

The battery voltage was measured at 12.4 VDC, and alarm messages were sent and properly received. The AFS unit was left over the weekend powered on, and to be checked first thing Monday morning. At 7:30 am on August 3, 1992, battery voltage measured 2.36 VDC, and there was no response from the system. The green Power On LED was not illuminated and the unit would not transmit any signals. The test had run for 64 hours. It is the assumption that 4 hours earlier, at 3:30 am, the system was, at the time, still sufficiently drained and inoperable. The unit was recharged and the test repeated.

The second test: repeat of Test Plan #1, August 5, 1992

Battery voltage was measured at 12.6 VDC at the beginning of the test, and the system was transmitting properly. At 2:00 p.m. on August 7, 1992, 54 hours into the 60 hour test, battery voltage measured 2.98 VDC, and there was no response from the system. The prototype has essentially failed the 60 hour test twice. The unit was recharged and tested again, monitoring the drop in battery voltage at periodic intervals to estimate its operational duration in its current configuration.

The third test: repeat of Test Plan #1, August 11, 1992

The test began with a measured battery voltage of 12.6 VDC and proper RF transmission. On the average the prototype was checked every 8.5 hours. At 27 hours, the system was operating normally and battery voltage measured 11.78 VDC. At 44 hours, the "LOW BATT" LED was illuminated on the BT2-3 panel and voltage measured 5.58 VDC. Alarm messages could still be initiated and received on the scanner. At 50 hours, voltage measured 5.11 VDC and transmissions were still possible. The system quit operating at 51.5 hours, with voltage being 3.5 VDC.

It was determined that the battery supply of the prototype was sufficient for 44 hours at best, far short of the 60-hour goal. A call to Monaco Enterprises, Inc. technical personnel had indicated that the battery was possibly faulty or damaged. A new, identical 6.5 AH 12-volt rechargeable battery was delivered along with some documentation showing the AFS drawing 0.085 amps yielding a 76-hour capacity for the battery.

The fourth test: repeat of Test Plan #1, August 21, 1992

With the replacement battery installed, system voltage measured 12.5 VDC. Alarm messages sent are received. A digital ammeter was installed in-line and measured system current draw at 0.116 amps. In theory, this indicates a useful battery life of 56 hours. The test was allowed to continue through the weekend. At 7:30 am Monday morning, 62.5 hours into the test, battery voltage measured 2.7 VDC and no transmissions were possible.

Theory and experiment have concluded that the current configuration of the prototype AFS cannot meet the 60 hour stand-alone duration requirements. A way must be found to reduce current draw or a larger, more powerful battery must be used. At this point, it is interesting to note that the prototype is using a UV flame detection sensor drawing 0.010 amps. The most recent notes on the Machine Vision flame detection system indicate its current draw to be on the order of 2.1 amps continuous at 12 volts DC, making it necessary for an even larger battery in future AFS models.

3.3 MANUAL PULL STATION TESTING

3.3.1 Test Description

The inclusion of a manually activated alarm station onto the prototype AFS allows personnel to initiate an alarm before a sensor can, if necessary. The purpose of this test is to verify that the hardware installed for this system works as expected.

This simple test involves making sure the AFS is fully charged, interrogating for proper RF transmissions, then activating the manual alarm (pulling the handle). Alarm messages stating the manual station has been activated should be received at the central Tx/Rx or the backup portable scanner.

3.3.2 Manual Pull Station Test Results

This test was successfully conducted on August 5, 1992. The prototype was powered up and the batteries had a full charge. To test communications, the AFS was interrogated by the central Tx/Rx for its status and received the correct replies. The manual alarm handle was then pulled and the alarm message was received at the central Tx/Rx. The system was reset and the test was repeated two more times with identical results.

3.4 FIRE/SMOKE TESTING

3.4.1 Test Description

The purpose of these experiments was to test the prototype's performance against real fires and smoke. The wireless smoke detectors and the UV flame detector were tested for responsiveness and sensitivity, and their ability to trigger an alarm condition to the AFS. The AFS communication electronics in turn should then relay the proper RF message to the central Tx/Rx station.

All of these tests were conducted in a specially built test structure which has the same cross-sectional geometry of a C-130 cargo bay. The length of the structure is approximately one-third (16 ft.) the full length of a cargo bay (Figures C-11 and C-12).

For the tests, radiated signal strength of the RF transmissions was padded down somewhat by using a Monaco-provided 50-Ohm dummy load antenna. This did not impair system performance. The purpose was to keep from interfering with the owners of that operating frequency, which were located approximately 12 miles away.

The equipment layout for each experiment was basically the same with only the height of the smoke detector being changed with respect to floor level. On the tests when the smoke detector was used, it was placed at either 6 ft. or 9 1/2 ft. (ceiling height). The pan containing the fire or smoke stimulus was always on the floor, near the wall, and directly across from the AFS (Figures C-13 through C-16).

The tests were not necessarily conducted in numerical order. Because of the temperamental nature of the digital recorders, some were repeated more than once to obtain the data. Other test numbers were skipped because sufficient test data was collected the first time. Tests were concluded at the time of alarm or four minutes, whichever came first. On the basis of Task 2 testing, four minutes seemed ample time for the AFS to detect and report the fire.

A quick-look summary of live fire test results can be found in Table C-1. A full set of all of the digitally recorded data for the live fire/smoke tests can be found in Annex B.

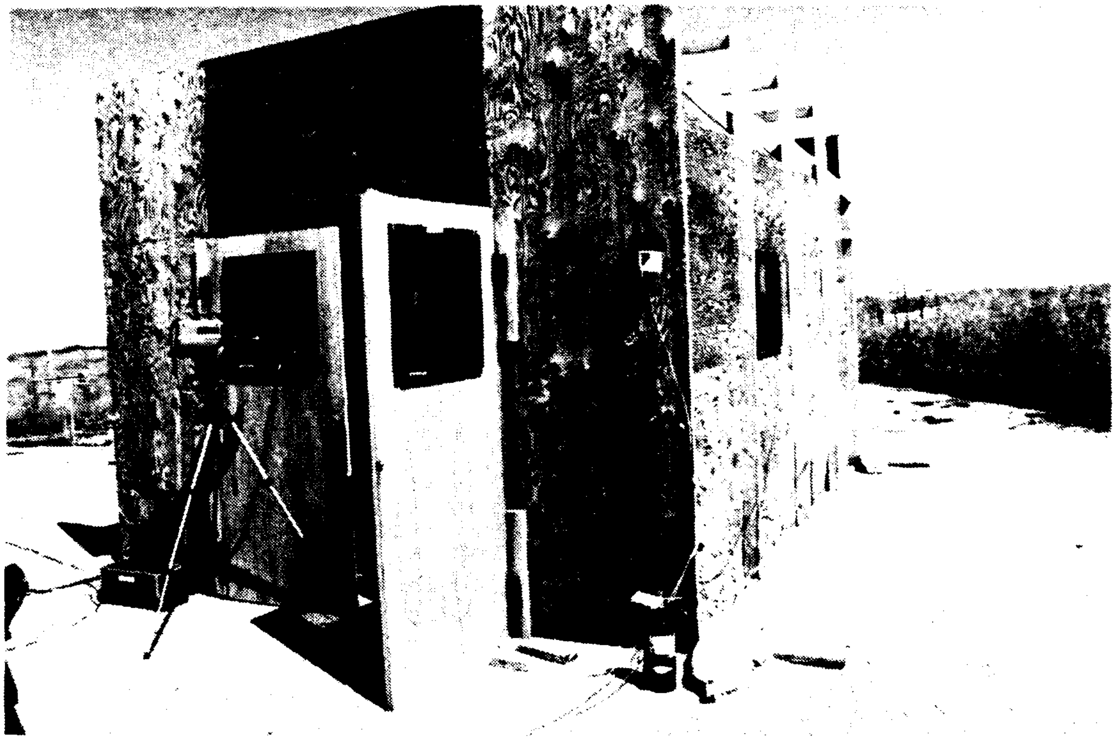


Figure C-11. Live Fire Testing Structure

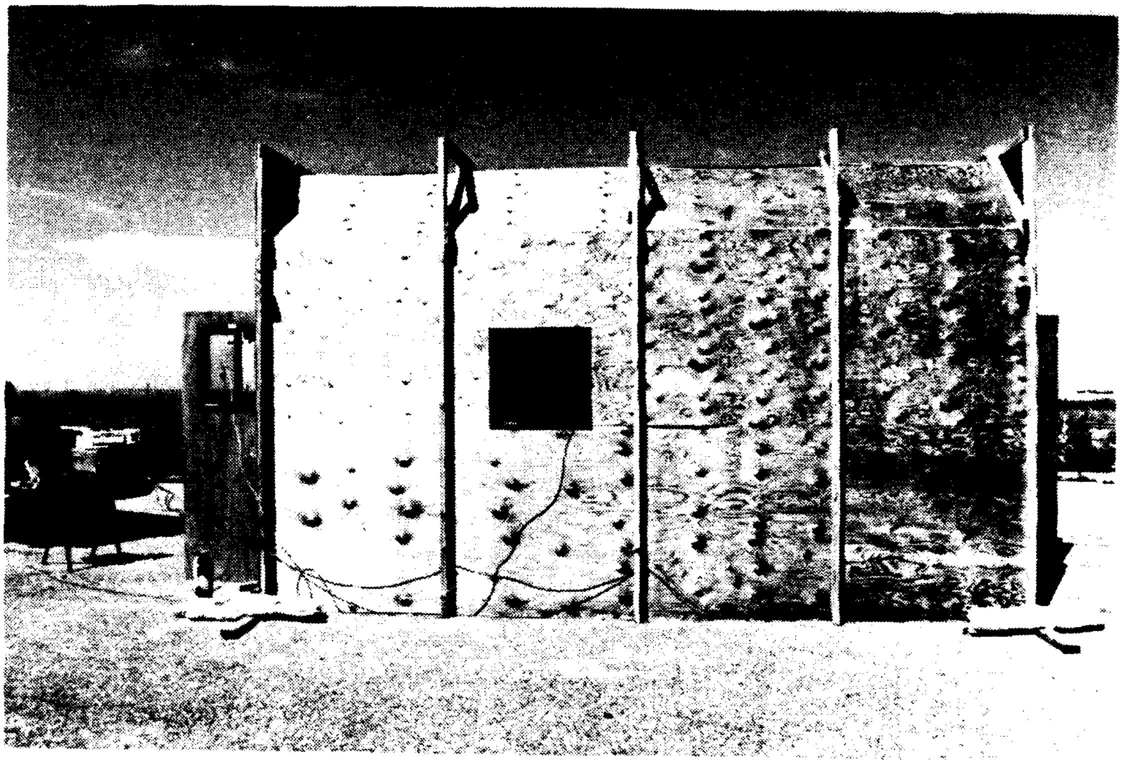


Figure C-12. Live Fire Testing Structure (Side View)

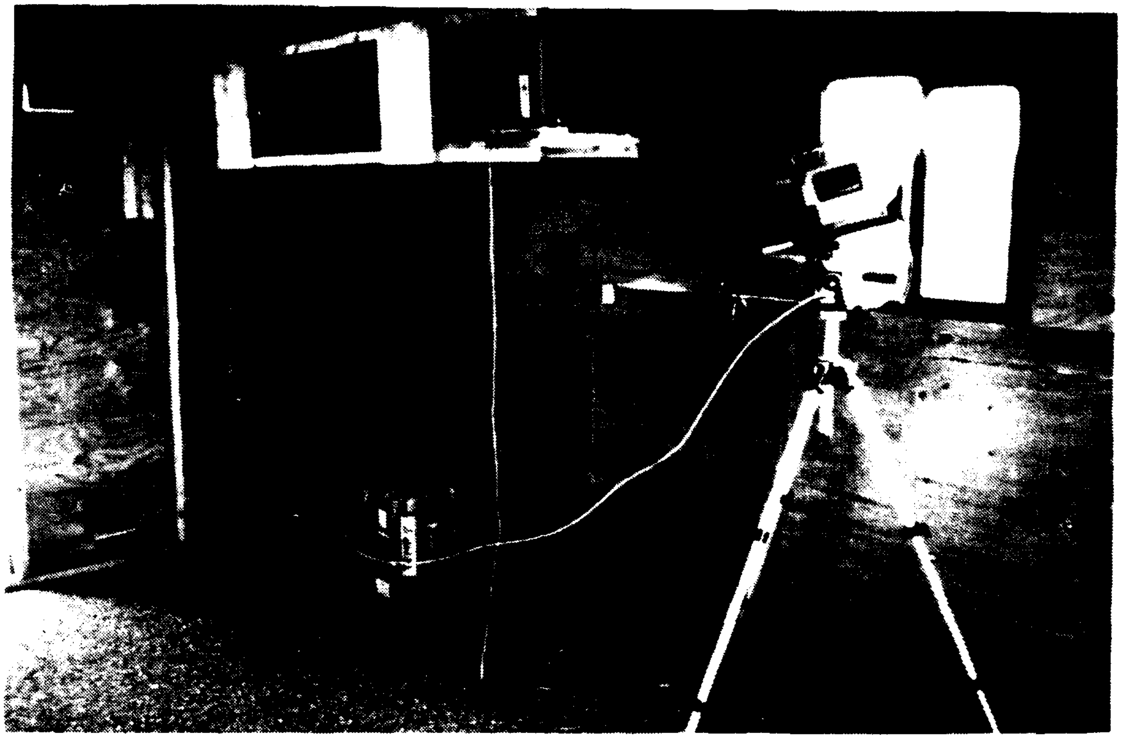


Figure C-13. Typical Equipment Layout (East Wall)

Figure C-14. Typical Paper/Trash Source (West Wall)

Figure C-15. Typical Jet-A Fuel Fire Source (West Wall)

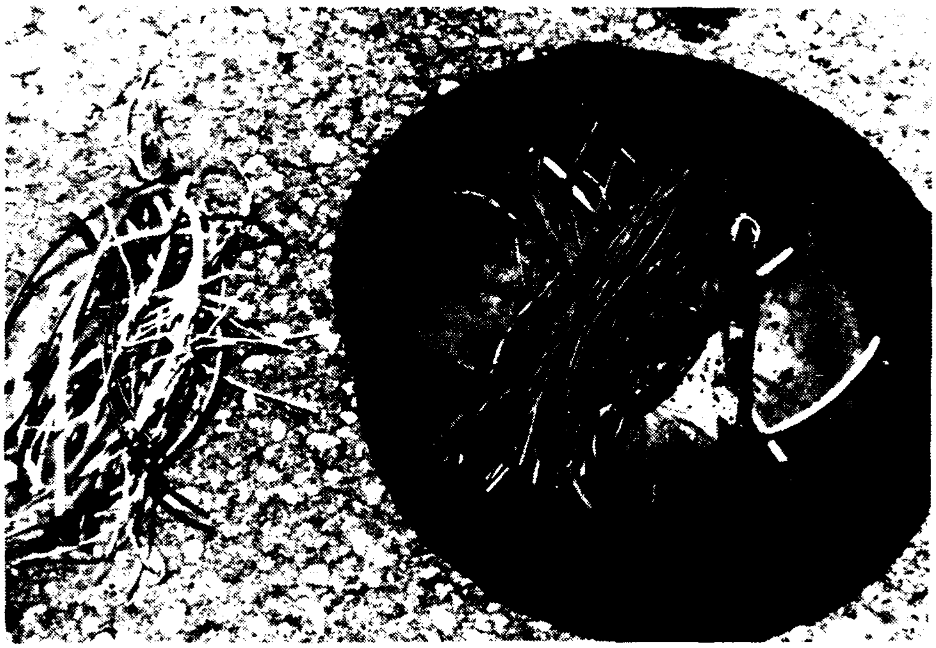


Figure C-16. Smoldering Electrical Wire Test Before/After

TABLE C-1. SUMMARY OF TASK 3 LIVE FIRE TESTING

Live Test No.	Smoke = S Fire = F	Source	Detector	Smoke Detector Height	Test Duration to Alarm	Max. Temp. at Smoke Detector	Smoke Obscuration at Alarm	Remarks
4	S	Electrical Wiring	Wireless Smoke	6 ft.	No alarm	N/A	(1.1%)	Melting wire never put off much smoke. No alarm. Very bad smell. No need to run a repeat test.
6	S	Electrical Wiring	Wireless Smoke	9.5 ft.	No alarm	N/A	(0.4%)	Melting wire never put off much smoke. No alarm. Very bad smell. No need to run a repeat test.
8	F	Paper/Trash	UV Flame	N/A	77 sec.	110^{o}F @ 105 sec.	N/D	77 seconds misleading. Alarm sounded when flames grew higher than the walls of the flame bucket.
9	F	Paper/Trash	Wireless Smoke	6 ft.	No alarm	170^{o}F @ 65 sec.	(2.5%)	Trash fire not smokey enough to alarm. Temp. reached triggering levels.
10	F	Paper/Trash	Wireless Smoke	6 ft.	No alarm	140^{o}F @ 100 sec.	(1.4%)	Trash fire not smokey enough to alarm. Temp. reached triggering levels.
10b	F	Paper/Trash	Wireless Smoke	6 ft.	143 sec.	180^{o}F @ 150 sec.	6.0%	More trash added for a larger, smokier fire. Temp. levels also increased.
11	F	Paper/Trash	Wireless Smoke	9.5 ft.	112 sec.	140^{o}F @ 75 sec.	3.9%	Alarm at detector - yes. No alarm message received at AFS or the central Tx/Rx.
12	F	Paper/Trash	Wireless Smoke	9.5 ft.	237 sec.	190^{o}F @ 90 sec.	N/D	Trash fire not very smokey. Took a while for density to build. Temp. at high level prior to smoke alarm.
13	F	Jet-A Fuel	UV Flame	N/A	Instantaneous	N/D	N/D	
14	F	Jet-A Fuel	Wireless Smoke	6 ft.	207 sec.	90^{o}F @ 240 sec.	5.9%	Receiver module at central Tx/Rx inoperative.
15	F	Jet-A Fuel	Wireless Smoke	6 ft.	50 sec.	110^{o}F @ 80 sec.	5.3%	Done shortly after Test 14. Possible lingering smoke by-products in shelter causing quicker response time.
16	F	Jet-A Fuel	Wireless Smoke	9.5 ft.	122 sec.	110^{o}F @ 160 sec.	3.5%	
17	F	Jet-A Fuel	Wireless Smoke	9.5 ft.	70 sec.	120^{o}F @ 130 sec.	4.6%	Done shortly after Test 16. Possible lingering smoke by-products in shelter causing quicker response time.

N/A = Not Applicable
N/D = No Data

3.4.2 Fire/Smoke Test Results

Below, a description and the results of each test are given.

Test #4, July 31, 1992

Source: Electrical Wiring
Detector: Wireless Smoke
Height: 6 ft.

A cast-iron pan was put on a hot plate, set on high, and allowed to reach maximum temperature. A handful of various types of electrical wiring (cut into 8-inch lengths) was then placed in the pan. The test ran a total of 7 minutes. The insulation on the wiring burned and melted, but no significant smoke was produced. By monitoring the output of the smoke obscuration detector, a maximum obscuration of 1.1% per foot was measured. The smoke detectors are rated at 3.1% per foot $\pm$0.5%. As there was no fire to speak of, no temperature measurements were take. The smell of the burning wire was very bad. No alarm was initiated.

Test #6, July 31, 1992

Source: Electrical Wiring
Detector: Wireless Smoke
Height: 9.5 ft.

As in Test #4, a handful of wiring was placed in a pan on a high-temperature hot plate. Again, the insulation on the wiring melted and burned away without producing any significant smoke. A maximum level of 0.4% obscuration per foot was recorded. There was no alarm, and the test was concluded at 4 minutes.

Test #8, July 21, 1992

Source: Paper/Trash
Detector: UV Flame

This test was run to verify that the UV sensor could recognize a trash fire and initiate an alarm. A fire was lit and the alarm sounded at 77 seconds into the test. The UV sensor actually was more responsive than the 77 seconds indicates. It was a slow-building fire, and the flames did not begin to peek over the walls of the flame bucket until approximately 70 seconds into the test. After the alarm was generated, the proper alarm message was received at the central Tx/Rx. The placement of the UV sensor inside the AFS unit only allows a 32° cone of vision - rather narrow. Therefore, the AFS was situated so that the UV sensor was

more or less pointed directly at the flame bucket (Figure C-17). Temperatures were recorded at the three locations of interest but are of no significance to the overall results of this test.

Test #9, August 5, 1992

Source: Paper/Trash
Detector: Wireless Smoke
Height 6 ft.

This was the first test against a trash fire with the smoke detector set at 6 ft. above floor level. Paper, cardboard, old rags and some weeds collected from around the test site were used as the source of the fire (as well as the source for all subsequent paper/trash fires). Smoke obscuration levels reached a maximum of 2.5% per foot, and there was no alarm during the four-minute duration of the test. The trash fire apparently just was not smoky enough to trip the alarm. It is interesting to note that the temperature measurement taken near the smoke detector reached 170^{O}F about 65 seconds into the test which probably would have triggered a heat sensor alarm, had the prototype been equipped with one. It will be recommended in the evaluation section of this report that some sort of heat detection device be a part of any subsequent models of the AFS.

Test #10, August 5, 1992

Source: Paper/Trash
Detector: Wireless Smoke
Height: 6 ft.

This is a repeat of Test #9. Identical equipment layout and procedures were followed. Again, the trash fire put out a lot of flames, but little relative smoke. Maximum smoke obscuration levels were recorded at 1.4% per foot. No alarm was generated during the four-minute test. Temperature levels near the smoke detector reached about 140^{O}F at 100 seconds into the test.

Test #10b, August 5, 1992

Source: Paper/Trash
Detector: Wireless Smoke
Height: 6 ft.

This was a repeat of Test #10, but this time more "trash" was placed in the bucket in an effort to build a smokier fire. An alarm sounded 143 seconds into the test and smoke obscuration levels reached 6.0% per foot at that time. Temperature near the smoke detector reached 180^{O}F at 150 seconds into the test. Even though the central Tx/Rx was operating properly prior to the test (Tx/Rx

communications always checked prior to each test), the central station did not receive the alarm message due to what is thought to be a faulty receiving module. The backup portable scanner did verify the alarm message.

<u>Test #11, July 31, 1992</u>

Source: Paper/Trash
Detector: Wireless Smoke
Height: 9.5 ft.

This test is similar to the previous three except the smoke detector was relocated to ceiling height. The fire was lit, and at 112 seconds only the smoke detector went into alarm. It has an integral horn of its own that sounds when the unit triggers. This time there seems to have been a communication breakdown between the wireless smoke detector and the supervised wireless security receiver unit in the AFS. Therefore, an alarm message was never received at the central station or the backup portable scanner. Cause for the failure is unknown, and this particular problem never happened again. Smoke obscuration reached 3.9% per foot at the time of alarm and temperature levels near the smoke detector reached $140^{O}F$ at about 75 seconds into the test.

<u>Test #12, July 23, 1992</u>

Source: Paper/Trash
Detector: Wireless Smoke
Height: 9.5 ft.

This test was similar to the previous paper/trash fire tests in that the fire put off a lot of flames and heat but relatively little smoke. The AFS did go into alarm at 237 seconds, and the alarm message was received by the portable scanner. Due to a malfunction in the smoke obscuration detection system or the recorder for that channel, there is no record of obscuration for this test. Temperatures near the smoke detector reached $190^{O}F$ at 90 seconds into the test.

<u>Test #13, August 5, 1992</u>

Source: Jet-A Fuel
Detector: UV Flame

This was a second test of the UV detector, this time against a fuel fire. To assure the fire was on the narrow field of view of the sensor, the AFS was positioned such that the sensor was pointed almost directly at the fire pan. The 12-inch diameter pan was filled with Jet-A fuel to about 1/8 in. deep. Through experience, it was found that the jet fuel is hard to light. To help get the pan fire going, a small sheet of newspaper was crumpled and soaked in the fuel. Matches

would easily light the paper which in turn would light the fuel. (The remaining Tests 14 through 17 are set up in an identical fashion.) As the fire was lit, the AFS went into alarm immediately. The AFS system was very responsive and the correct alarm message was received at the central Tx/Rx.

Test #14, August 5, 1992

Source: Jet-A Fuel
Detector: Wireless Smoke
Height: 6 ft.

This was the first test for the AFS wireless smoke detector set at 6 ft. above floor level against a fuel fire. The fire in the pan was readied (as described in Test #13) and lit. At 207 seconds into the test, an alarm was generated by the smoke detector, and the alarm message was received by the scanner, but not by the central Tx/Rx (again faulty, intermittent receiver module). Smoke obscuration was recorded at 5.9% per foot at alarm, and the temperature rose to only 90^{O}F near the smoke detector. All doors and windows for the structure were opened to clear the smoke, and preparations were made for the next test.

Test #15, August 5, 1992

Source: Jet-A Fuel
Detector: Wireless Smoke
Height: 6 ft.

This was the second fuel fire test with the detector at 6 feet. An alarm was generated by the smoke detector at 50 seconds into the test, and the alarm message was received by the portable radio frequency scanner. Smoke obscuration reached 5.3% per foot at the time of alarm and temperature near the smoke detector rose to a maximum of 110^{O}F approximately 80 seconds into the test.

Test #16, July 31, 1992

Source: Jet-A Fuel
Detector: Wireless Smoke
Height: 9.5 ft.

The same fuel fire set up as described in Test #13 and the smoke detector has been moved up to ceiling height. An alarm was generated by the smoke detector 122 seconds into the test at which time smoke obscuration was measured at 3.5% per foot. Temperature near the smoke detector was recorded as being a maximum of 110^{O}F at 160 seconds into the test. The central station received the correct alarm message.

Test #17, July 31, 1992

Source: Jet-A Fuel
Detector: Wireless Smoke
Height: 9.5 ft.

This was the last test in the live fire/smoke series and the second test under this configuration. The results of this test show smoke obscuration at 4.6% per foot at the time of alarm - 70 seconds from the time the fire was lit. Temperature near the detector reached 120°F at 130 seconds into the test. The central station received the alarm message.

Tests 15 and 17 were conducted shortly after 14 and 16 (respectively). It is believed that the quicker response time for Test 15 and 17 were a result of possible lingering combustion by-products from the previous test.

3.5 WIRELESS SMOKE DETECTOR DISTANCE TESTING

3.5.1 Test Description

The remote wireless smoke detectors sense smoke by photoelectric means, and when levels reach a certain point (3.1% $\pm$ 0.5%), the detector initiates an alarm. Its internal horn activates and a radio frequency message is sent to the wireless receiver in the prototype AFS. The purpose of this test is to determine the maximum unobstructed distance the two can be separated and still communicate.

3.5.2 Wireless Smoke Detector Distance Test Results

Referred to as Test #18 in the Task 3 Test Plan, this was conducted at the AFS test site. Battery voltage measured 12.15 VDC (12 VDC normal) and 8.83 VDC (9 VDC normal) in the AFS and smoke detector, respectively. Alarm signals were generated by a wireless smoke detector. After each successful communication, the distance between the detector and the AFS was increased by 25-foot intervals. A good test at 75 feet was recorded. Two tests at 100 feet were unsuccessful. The test at 75 feet was repeated but was unsuccessful this time. The gap was then reduced and reliable transmissions were occurring at 60 feet (Figure C-18).

4.0 EVALUATION AND CONCLUSIONS

The prototype Aircraft Fire Sentry system has essentially passed all tests as set forth in the Task 3 Test Plan with the exception of the 60-Hour Duration Test. The 6.5 AH rechargeable battery does not have the capacity to power the AFS in its current configuration for the full 60 hours. Current draw for the AFS system was measured at 0.116 amperes. In theory this battery has a capacity of 6.5 AH/0.116 = 56 hours. Under operating conditions, it is estimated that the system is reliable through about 36 hours based on the drop in voltage over time. This suggests that a larger battery is required to meet the 60 hours in the system's current configuration.

To have effective UV flame detection coverage, the prototype AFS would need additional UV sensors -- one looking out each side of the unit. They should be placed further outward so each would have a better cone of vision. The UV sensor currently installed in back should be moved to look out the front. Assuming the AFS would be placed in the aircraft with its back against the fuselage wall, this could give the assembly close to a 270^{o} cone of vision. It would also increase the unit's power requirements, which would require an even larger battery.

Since the early stages of this project, the Machine Vision flame detection system has been considered a possible candidate for flame detection in the AFS. That system, however, has been under development during the entire duration of this project, and no unit was ever obtained for AFS integration or testing purposes. What is known is the rough size and power requirements, which are 10" x 10" x 4" and 25 watts (12 VDC @ 2.1a). These power requirements are substantially higher than 3 standard UV sensors. -Cost of a Machine Vision system is unknown at this time. A sketch of the system provided for this project is in Annex C.

The wireless smoke detectors were very responsive within their operating range and seem to be a good choice for deployment in the aircraft. The length of the largest cargo bay is approximately 150 feet (C-5A) which would require at least 2 detectors, as their range was determined to be 75 feet maximum. In this arrangement, the AFS would be placed mid-bay and a detector placed approximately midway between the AFS and the ends of the bay. On the basis of response times to the real fire/smoke testing, the best height for the smoke detector is up near the ceiling -- certainly above the level of any open doors or windows, etc.

During the live fire/smoke series of testing, data has shown that temperature in the structure near the smoke detector in some cases increased to heat sensor triggering levels before the smoke alarm sounded. It is recommended that for any subsequent model of AFS, a suitable heat sensor be integrated with the portable wireless smoke detector.

The prototype AFS can be transported and deployed by a single person in a matter of minutes. It would be desirable, however, to decrease its bulk somewhat in size and weight. This would probably require considerable re-design.

The main system antenna is a 40-inch collapsible with a magnetic base and a 12-foot length of cable. The best place for the magnetic base to be placed is on the top steel carrying handle on the AFS.

In general, the RF communication electronics were reliable. However, during the live fire/smoke series, intermittent problems arose in both the AFS and the central Tx/Rx. The three issues were: 1) sometimes a central Tx/Rx interrogation of the AFS (BT2-3) required more than one try before a response; 2) during one test, the alarm signal from a smoke detector was not received at the AFS receiver; and, 3) the D-500 Plus central Tx/Rx had what was believed to be a faulty intermittent receiving module. A portable radio frequency scanner was used as a back-up to verify alarm signals.

The prototype AFS could be produced and deployed as is. Its performance could benefit from a few modifications; namely, an integral heat sensor and a more powerful battery. Through testing, the AFS has been established as an effective means of detecting and reporting fires on unattended large cargo aircraft.

5.0 COST OF THE PROTOTYPE AFS

The Monaco Enterprises, Inc. labor and material costs for the layout, assembly, Fairchild AFB testing, documentation, and travel to Denver were \$13,882.00. BT2-3 electronics from the small scale model were used in the prototype and not included in the above cost.

The approximate cost for each prototype AFS copy is \$5,000.00

APPENDIX C

ANNEX A

TASK 3 TEST PLAN

(The reverse of this page is blank.)

AIRCRAFT FIRE SENTRY

TASK 3

FINAL PROTOTYPE TEST PLAN

Prepared for:

Prepared for Headquarters, Air Force Engineering Services Center,
Scientific and Engineering Technical Assistance (SETA)
Tyndall Air Force Base, Florida 32403

Contract Number F08635-88-C-0067
Supplemental Support Group Subtask (SSG) 3.14.1

Prepared by:

Applied Research Associates, Inc.
7114 W. Jefferson Avenue, Suite 305
Lakewood, Colorado 80235

Written by:

Robert Mugele

Peter T. Dzwilewski
Principal Investigator

Date: 16 July 1992

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 SCOPE

This test plan will be used to demonstrate the operation of the prototype design of the Aircraft Fire Sentry (AFS) system. Evaluation of the overall AFS prototype system will be based on performance during this test series.

1.2 OBJECTIVES

The objectives of the testing are: 1) to demonstrate the AFS system's ability to detect fires using smoke and flame detectors; 2) determination of the optimal placement of the system, with respect to height above floor level in the aircraft; 3) determination of the estimated time between fire/smoke initiation, detection, and notification of a receiver station, for a limited set of test conditions; and, 4) to verify correct operation of the AFS components, especially the system's ability to notify the fire department (the central transmitter/receiver) via a radio frequency (RF) link.

1.3 APPLICABLE DOCUMENTS

Monaco Enterprises, Inc. Installation, Operation and Maintenance Manuals for the D-500 Plus Advanced Wireless Information Management Alarm Receiving and Reporting System, and the Monaco BT2-3 Building Transceiver.

Aircraft Fire Sentry Statement of Work (SSG 3.14.1).

1.4 FACILITIES

The tests will be conducted at Applied Research Associates, Inc. (ARA) Rocky Mountain Division (RMD) facilities. Most of the testing, including all live fire and smoke tests, will be run at the ARA-RMD remote test site. This location, ideally suited for AFS testing, is approximately 30 miles east of the city of Denver. This secure site is furnished with electrical power, telephone, and a work/storage shop. A fire testing structure has been constructed at the test site specifically for AFS purposes.

Component checkout and the 60 hour operational duration test will be carried out in the lab at ARA's Lakewood, Colorado office.

1.5 AIRCRAFT FIRE SENTRY (AFS) SYSTEM DESCRIPTION

The AFS system essentially consists of a remote transmitter/receiver station which has been modified to include smoke detection, flame detection, and a manual pull station. This unit would be placed inside of parked cargo aircraft. It will be referred to as the remote Tx/Rx, or RTR in this test plan. An audible alarm and strobe will be packaged together and suitably attached to the exterior of the aircraft (or in this case, the test structure). This assembly will be connected to the remote Tx/Rx by a predetermined length of cable provided with prewired plug-in connectors. The remote Tx/Rx will be communicating its status by radio frequency link to a central transmitter/receiver (central Tx/Rx, or CTR) station. This unit would generally be located at the base fire department. For this test series, the central Tx/Rx will be placed just outside of the test structure.

The remote Tx/Rx basic unit has many of the same components and operating principles as the Monaco BT2-3. The central Tx/Rx is a Monaco D-500 Plus. All tests conducted under this test plan will be carried out using Monaco provided 50 Ohm dummy load antennas in place of the BSA-1 VHF Omnidirectional Antenna Assembly.

During all testing, the AFS remote Tx/Rx will be operating on its own internal battery power. Battery voltage will be checked after each test and recharged if necessary.

1.6 DOCUMENTATION

Photodocumentation of the AFS hardware and selected test event setups will be done with a 35 mm SLR camera. Color video recording of all of the live testing (smoke and fire) will also be done.

During the live testing, electronic data recorders will capture smoke density and temperature information. Field notes will be recorded in a lab notebook during each test. These notes will then be reduced to report form and included along with the data plots and black and white photography for presentation in the Task 3 report.

2.0 TEST VARIATIONS

2.1 TYPES OF TESTS

Four kinds of tests will be conducted to test the functional performance of the prototype. They are: a) the 60-hour operational, b) the manual pull station, c) the live tests, which include smoke alone and flaming fire stimulus, and d) distance testing between the smoke detector and the RTR. In combination, these tests are designed to verify proper operation of all of the individual components or assemblies that make up the AFS. Each type of test will be repeated and the results compared to assure consistency.

2.1.1 60 Hour Operational Duration

The objective of the 60 hour test is to satisfy the requirement that the AFS remote unit is capable of stand-alone operation for a minimum of 60 continuous hours.

The prototype AFS remote Tx/Rx will always operate under its own internal battery power whenever it is installed for use in an aircraft. Therefore, the batteries must provide enough power to operate the detectors and transmitter/receiver modules for extended periods (60 hours) without an AC recharge. The 12 volt rechargeable batteries which power the unit will always be verified fully charged before any test is begun.

This type of test will be run twice, varying the ambient temperature at which the unit is operating. The first test will be at 72°F, and the second test will be at 33°F.

If the unit is still responding correctly to central Tx/Rx interrogations, and battery voltage measurements are reasonably strong at the 60 hour mark, the tests(s) will continue to determine the ultimate duration under those conditions.

2.1.2 Manual Pull Station Alarm

Even though the remote AFS unit operates unattended, it is desirable to have a means of manually triggering an alarm condition. If personnel happen to be in a situation where they notice a fire before the unit's sensors do, they must have the ability to initiate an alarm. To meet this need, a manual pull alarm will be included on the remote Tx/Rx.

The objectives of this test are: 1) to check the operation of the manual pull handle modification to the AFS remote unit, and 2) to verify the system's ability to notify the central Tx/Rx by RF link that the manual alarm at a specified location has been tripped.

2.1.3 Live Tests

The objectives for these tests are to demonstrate the operation of the AFS system under actual live fire/smoke conditions. These tests shall demonstrate the system's ability to detect and report fires using smoke and flame detectors only, aid in the determination of the optimal placement of the system in an aircraft, and provide data as to the expected elapsed time between fire initiation, detection, and reporting.

The two types of detectors associated with the prototype are photoelectric smoke and UV flame. The smoke detector will be placed at locations 6 feet and 9.5 feet above the floor for each fire stimulus. This will help determine where it is the most responsive. These wireless remote smoke detectors transmit their trigger signal via RF to the RTR. The RTR will always be located on the floor, just below the detector.

A commercial UV flame detector is the other type used in the prototype. This device will illustrate that the AFS has flame detection capabilities. However, this UV unit is only a stand-in replacement for the "machine vision" unit which is currently under development and ultimately to be installed in the AFS remote Tx/Rx for flame detection purposes.

Fourteen separate live tests will be conducted. The first four will be smoke tests using smoldering electrical wiring as stimulus for the AFS. Short lengths of wiring will be placed on a hot plate and brought up to a temperature to burn off the insulation.

The next five tests will subject the AFS detectors to a flaming fire consisting of a paper/trash source. The first test of this series will be a flame detection test. If this test is successful, the UV flame detector will be disconnected and the remaining four tests will concentrate on the responsiveness of the smoke detector.

The last five tests will be JP-4/Jet-A fuel fire tests. Again, the first test in this series will verify UV flame detection and the remaining four will concentrate on smoke detection responsiveness at the 6 and 9-1/2 feet heights.

The pan containing the smoke and fire stimulus will always be on the floor next to the wall opposite from the AFS remote Tx/Rx unit. Horizontal distance between walls is twelve feet. An illustration showing equipment layout for these live tests is shown on Figure C-A-1.

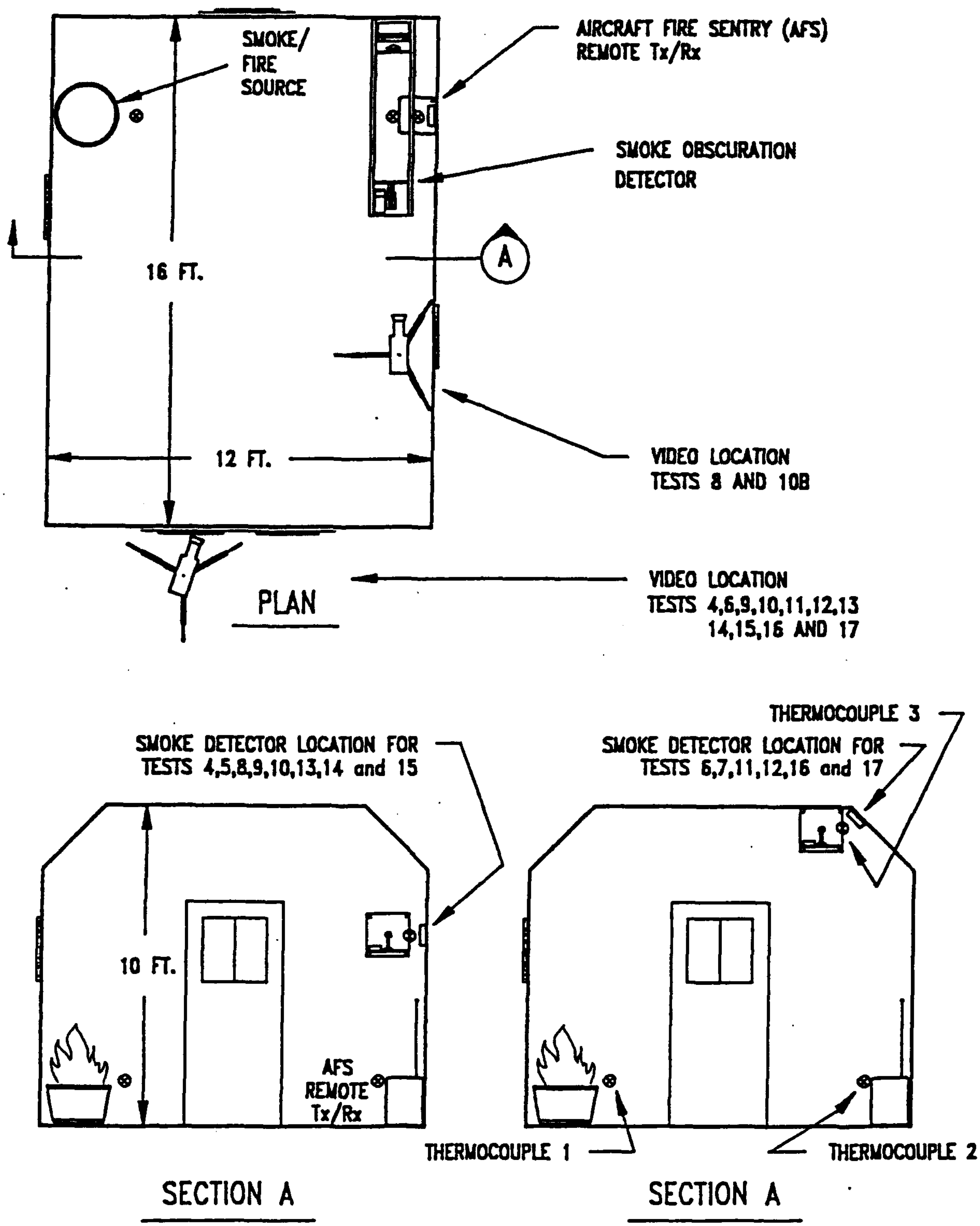


Figure C-A-1. Equipment Layout (Live Tests)

2.1.3.1 Instrumentation

During the live testing, smoke density will be monitored near the AFS remote smoke detector and recorded by a data acquisition system. These measurements will be taken between the source and the remote unit, approximately 12 inches from the unit. Recorded output of the smoke density device will be in terms of voltage versus time. Reduction of this data will change it to percent obscuration per foot versus time.

Temperature measurements will also be taken by fast response thermocouples and recorded by the data acquisition system. The three locations of interest are near the fire source, near the AFS remote Tx/Rx and near the remote smoke detector unit. This data will indicate if the temperatures near the AFS increase to heat sensor triggering levels before an alarm is initiated by another detector (flame or smoke).

The time duration of each test will be recorded from fire/smoke initiation to alarm. This measurement will be backed up by a hand-held stopwatch.

A portable RF scanner, preset to the AFS systems' operating frequency (138.925 Mhz), will be operating independently of the AFS and used as a backup to verify RF transmission to the central Tx/Rx.

Color video recording of each live test will also be done.

2.1.4 Smoke Detector Distance Test

The smoke detectors of the AFS prototype are wireless photoelectric type units which transmit the trigger signal via RF to the remote transmitter/receiver assembly. Their operating frequency is different than that used by the main system transmitters in the RTR and CTR. Once the RTR has received this signal, it in turn transmits the alarm message to the CTR. To complete the evaluation of the AFS, distance testing between the smoke detector and the RTR will be done. The tests will be conducted outside, with no obstructions (walls, boxes, etc.) between the two units. The smoke detector will be manually activated at 25-foot intervals up to 150 feet (which is the approximate length of the largest cargo bay). If successful at 150 feet, the ultimate clear space range will be determined.

2.2 LIST OF TESTS - TASK 3 PROTOTYPE

1. 60 hour operational, 72°F, ambient environment

(a) ~~2. 60 hour operational, 33°F, ambient environment~~

3. Manual pull station alarm, reset and repeat

4. Live-smoke, smoldering electrical wiring, AFS at 6 ft.

(b) ~~5. Repeat of Test 4~~

6. Live-smoke, smoldering electrical wiring, AFS at 9.5 ft.

(c) ~~7. Repeat of Test 6~~

8. Live-fire, paper/trash; AFS at 6 ft., smoke detector off (UV flame test)

9. Live-fire, paper/trash, AFS at 6 ft., UV detector off

10. Repeat of Test 9

11. Live-fire, paper/trash, AFS at 9.5 ft., UV detector off

12. Repeat of Test 11

13. Live-fire, JP-4/Jet-A, AFS at 6 ft., smoke detector off (UV flame test)

14. Live-fire, JP-4/Jet-A, AFS at 6 ft., UV detector off

15. Repeat of Test 14

16. Live-fire, JP-4/Jet-A, AFS at 9.5 ft., UV detector off

17. Repeat of Test 16

18. Remote RF smoke detector distance testing (between detector and Remote Tx/Rx)

Notes:

(a) Test 1 conducted 4 times, no response at 60 hrs. Test 2 unnecessary.

(b) Test 4 negligible smoke, no alarm. Test 5 unnecessary.

(c) Test 6 negligible smoke, no alarm. Test 7 unnecessary.

3.0 TEST PROCEDURES

3.1 60 HOUR TEST

Instrumentation required:

- AFS remote Tx/Rx
- AFS central Tx/Rx
- 35 mm camera
- voltmeter

Outline of test procedure:

1. Note date, time, location of test, and test operator
2. Record ambient temperature at unit location
3. Photograph AFS setup with 35 mm camera
4. Verify batteries in remote Tx/Rx are fully charged with the voltmeter (full charge = 12+ VDC)
5. Power up remote unit and verify RF link by central Tx/Rx interrogation
6. Leave AFS remote Tx/Rx on for 60 hours
7. Check RF link at the 60 hour mark by:
   a. manual pull - record results
   b. central Tx/Rx interrogation - record results
8. Check and record battery voltage
9. If unit is still responding and battery voltage measures 8+ VDC, continue test and check system response every four hours (when practical)
10. Record ultimate operating time
11. Note any test or system anomalies

3.2 MANUAL TEST

Instrumentation required:

- AFS remote Tx/Rx
- AFS central Tx/Rx
- 35 mm camera
- voltmeter

Outline of test procedure:

1. Note date, time, location of test, and test operator
2. Setup AFS - connect horn/strobe/antenna assemblies
3. Photograph system setup with 35 mm camera
4. Verify remote unit fully charged with voltmeter
5. Power up remote unit and verify RF link by central Tx/Rx interrogation
6. Activate manual pull station handle
7. Record response
8. Restore handle
9. Record response
10. Repeat test two more times
11. Note any test or system anomalies

3.3 LIVE TEST

Instrumentation required:

- AFS remote Tx/Rx
- AFS central Tx/Rx
- 35 mm and video cameras
- voltmeter
- smoke density measurement system
- temperature measurement system
- data recorders
- stopwatch
- fire extinguisher and self-contained breathing apparatus
- smoke/fire sources
- portable RF scanner (backup to central Tx/Rx)

Outline of test procedure:

1. Note date, time, location of test, and test participants
2. Note test number (which defines setup)
3. Configure AFS and test equipment
4. Note height of AFS and smoke/fire source
5. Photograph test setup with 35 mm camera
6. Verify remote unit is fully charged with voltmeter
7. Power up remote unit and check the RF link by central Tx/Rx interrogation
8. Power up all other equipment and verify it is operational
9. Prepare smoke/fire source
10. Note all initial parameters
11. Turn on video camera
12. Ignite source
13. Begin data recording
14. Continue until alarm
15. Record response:
    a. time (test duration)
    b. central Tx/Rx message
    c. real time parameters (voltages, temperatures)
16. Shut off video
17. Shut off recorders
18. Extinguish fire/evacuate smoke
19. Shut off remote unit alarm
20. Check all equipment for damage
21. Check recorded data
22. Note any test or system anomalies
23. Reset equipment and configure for next test

3.4 REMOTE RF SMOKE DETECTOR DISTANCE TEST

Instrumentation required:

- AFS remote Tx/Rx
- AFS central Tx/Rx
- remote RF smoke detector
- portable RF scanner
- 100 ft. tape measure

Outline of test procedure:

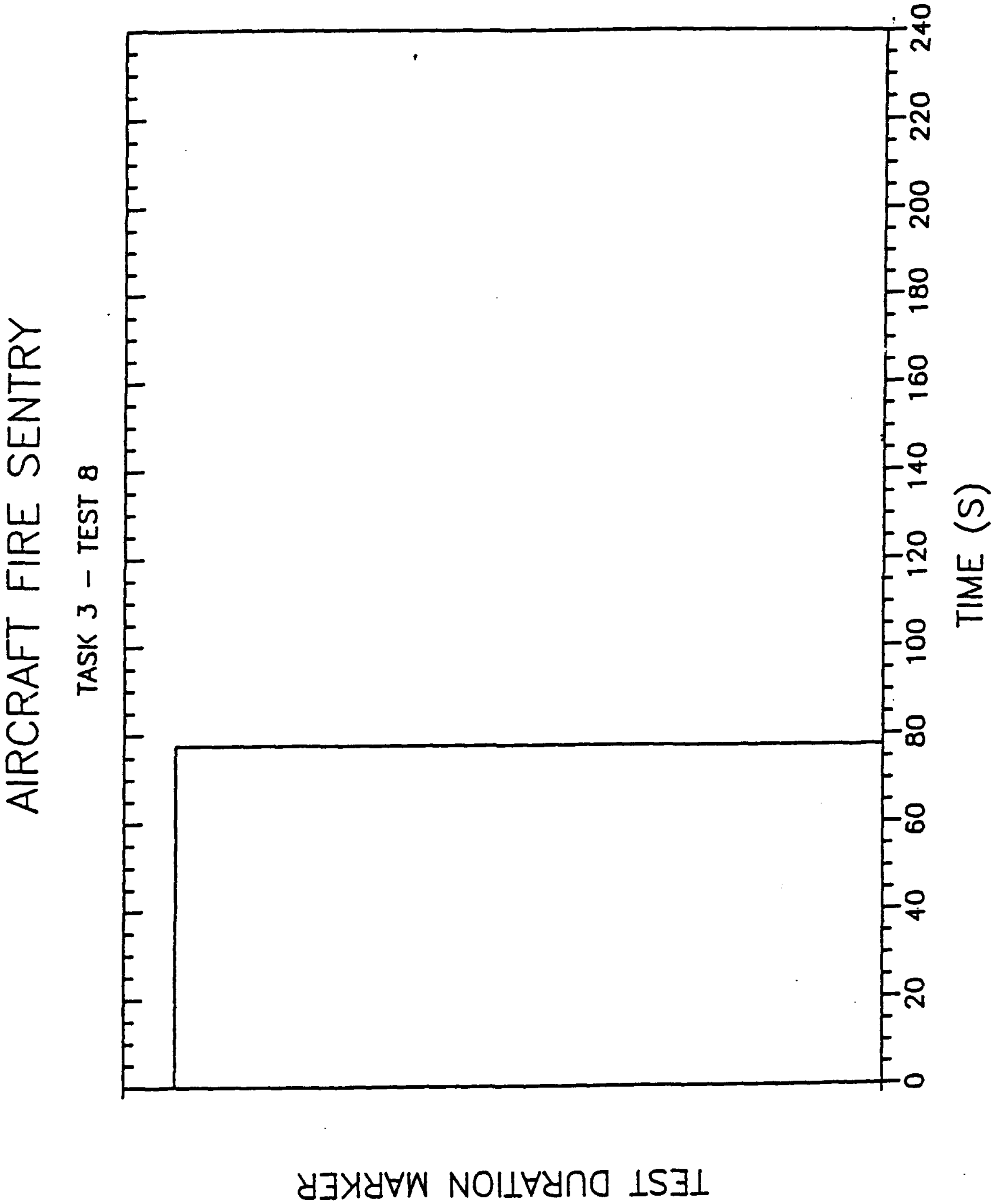
1. Note date, time, location of test and participants.
2. Verify all batteries and equipment is fully charged and operating properly.
3. Lay out 100 foot tape and place remote Tx/Rx at one end.
4. Manually trigger the RF smoke detector at 25 foot intervals, verify signal received.
5. Continue to 150 feet.
6. If practical, determine ultimate range.

APPENDIX C

ANNEX B

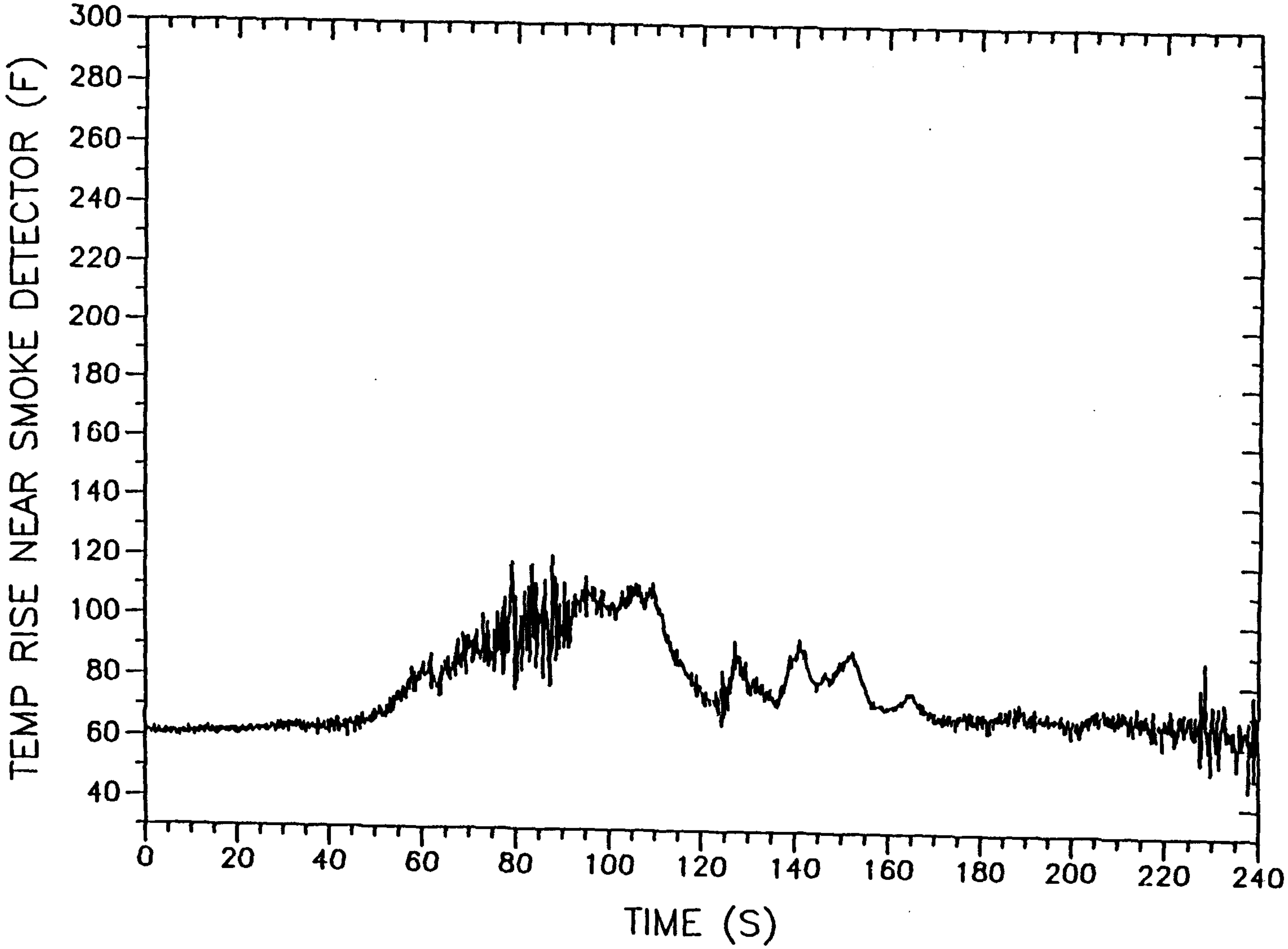
DIGITALLY RECORDED DATA

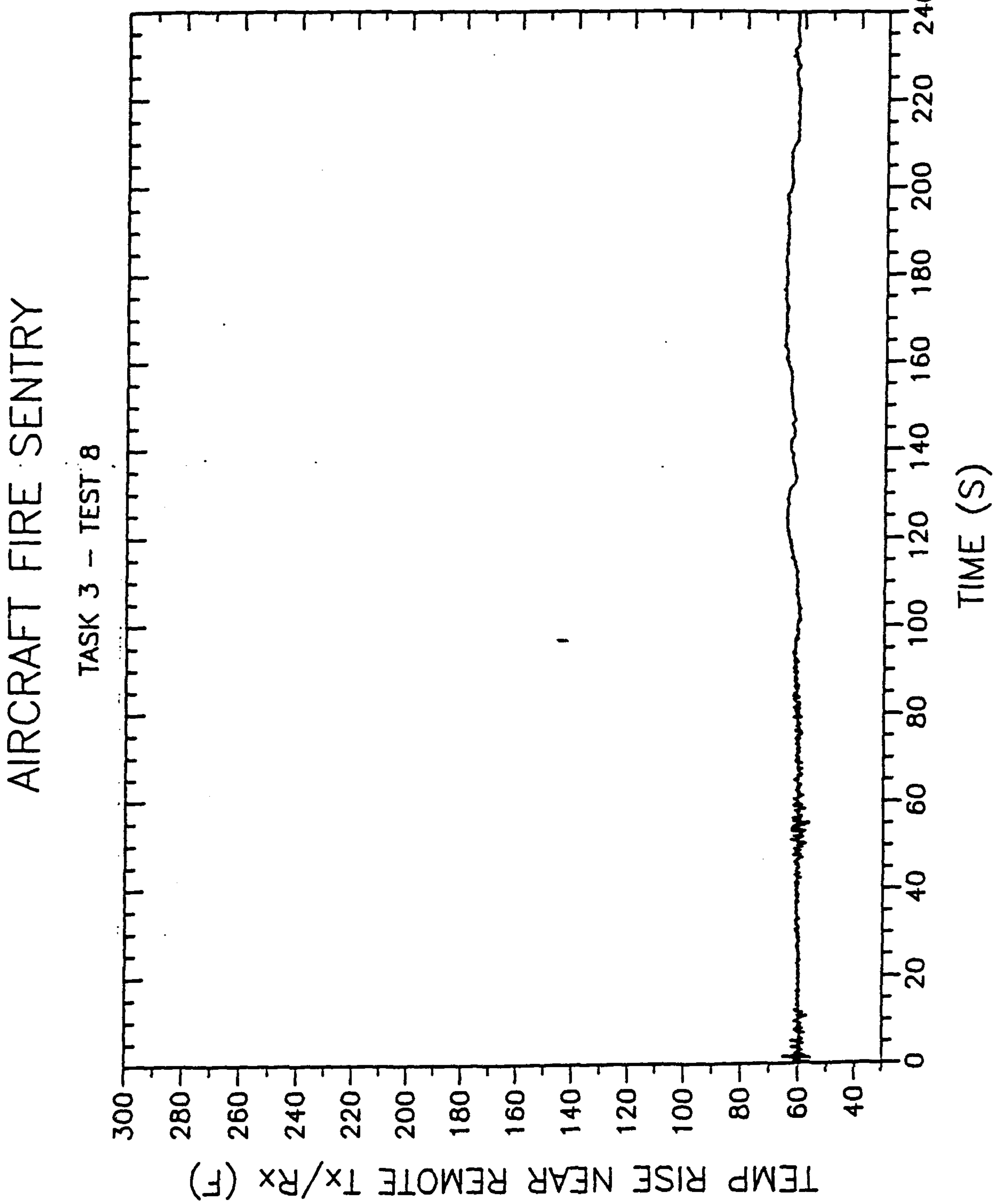
(The reverse of this page is blank.)


AIRCRAFT FIRE SENTRY
TASK 3 – TEST 8
TEST DURATION MARKER
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240

AIRCRAFT FIRE SENTRY

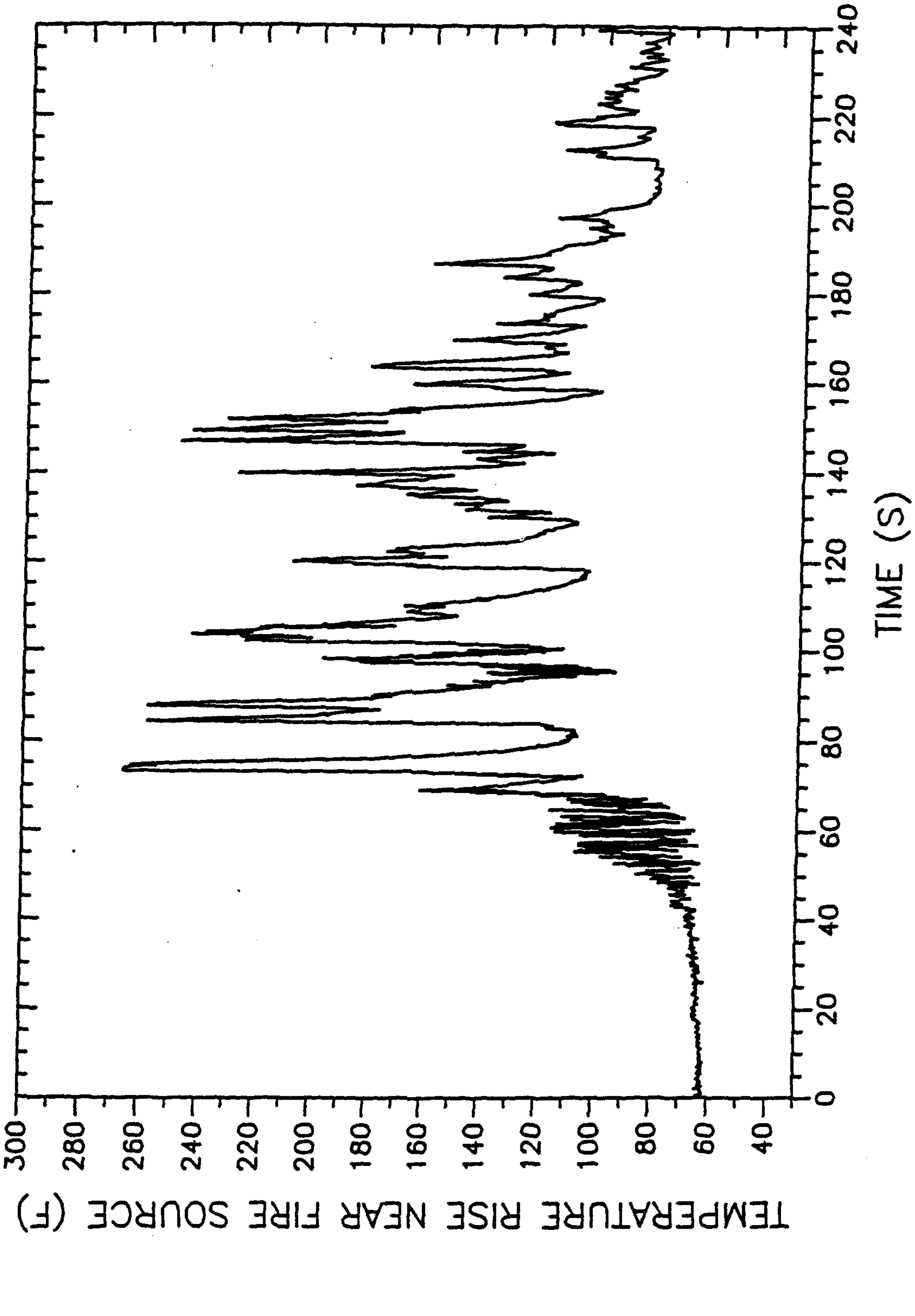
TASK 3 – TEST 8

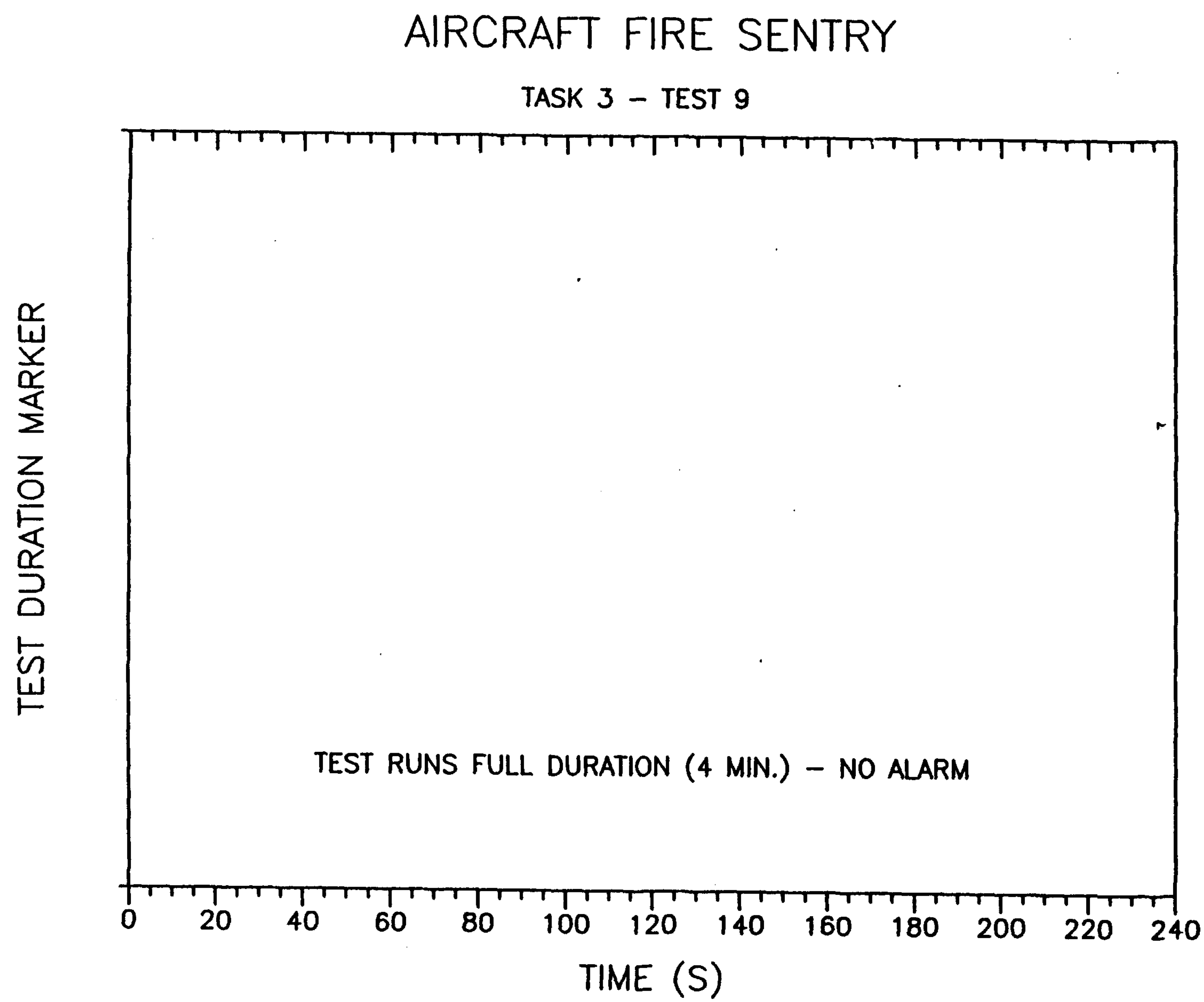


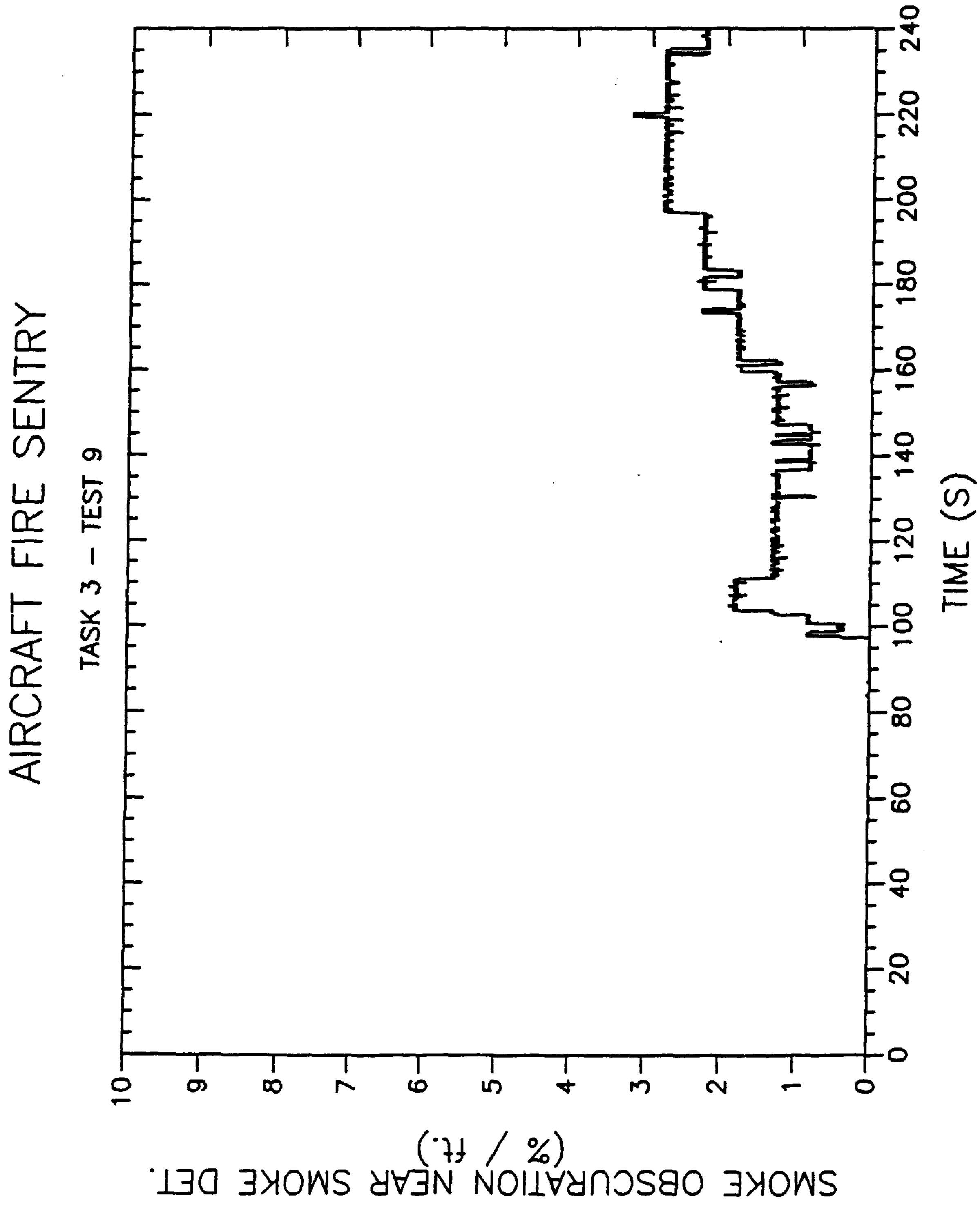

AIRCRAFT FIRE SENTRY
TASK 3 - TEST 8
TEMP RISE NEAR REMOTE Tx/Rx (F)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240

AIRCRAFT FIRE SENTRY

TASK 3 – TEST 8

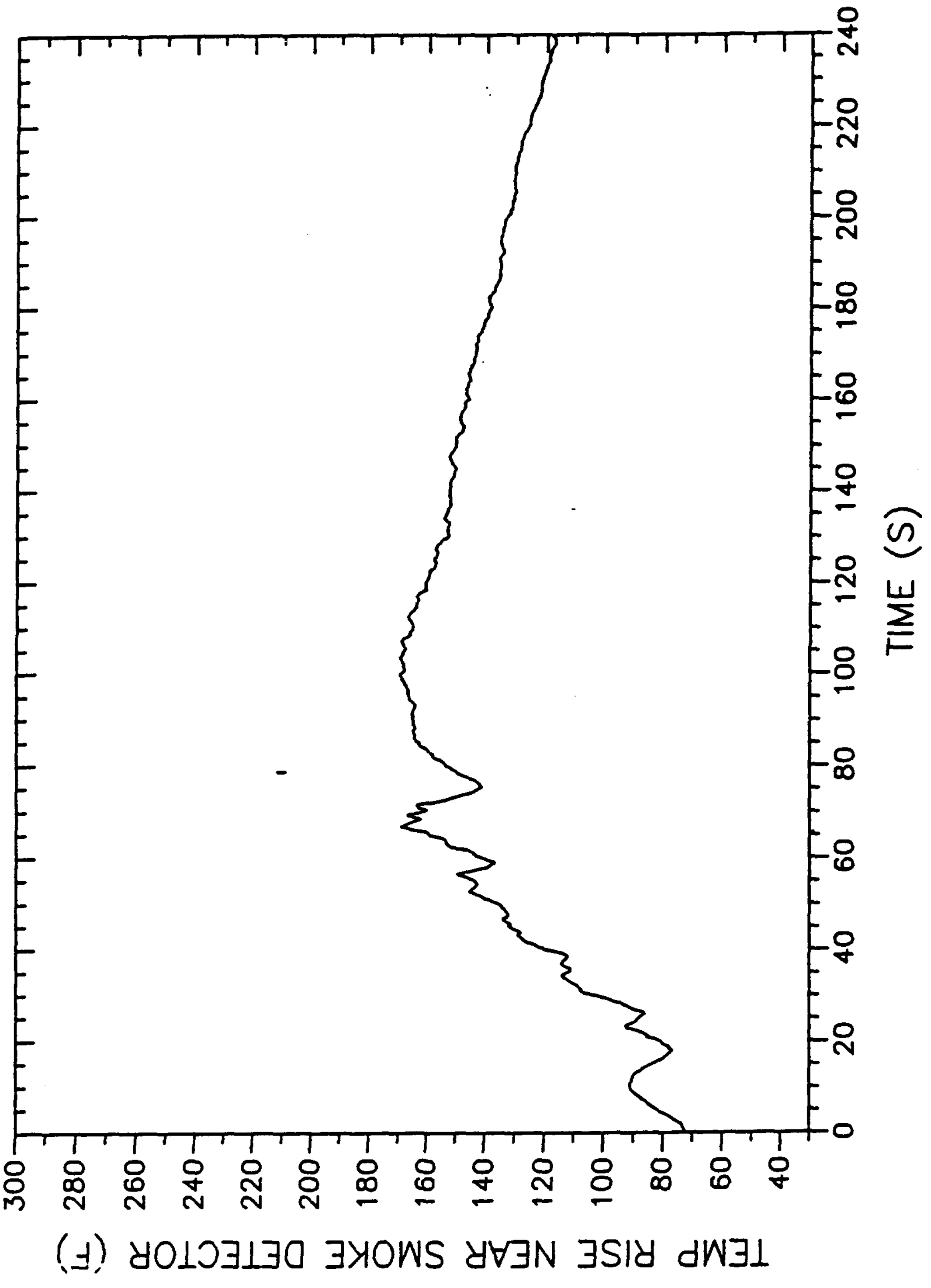


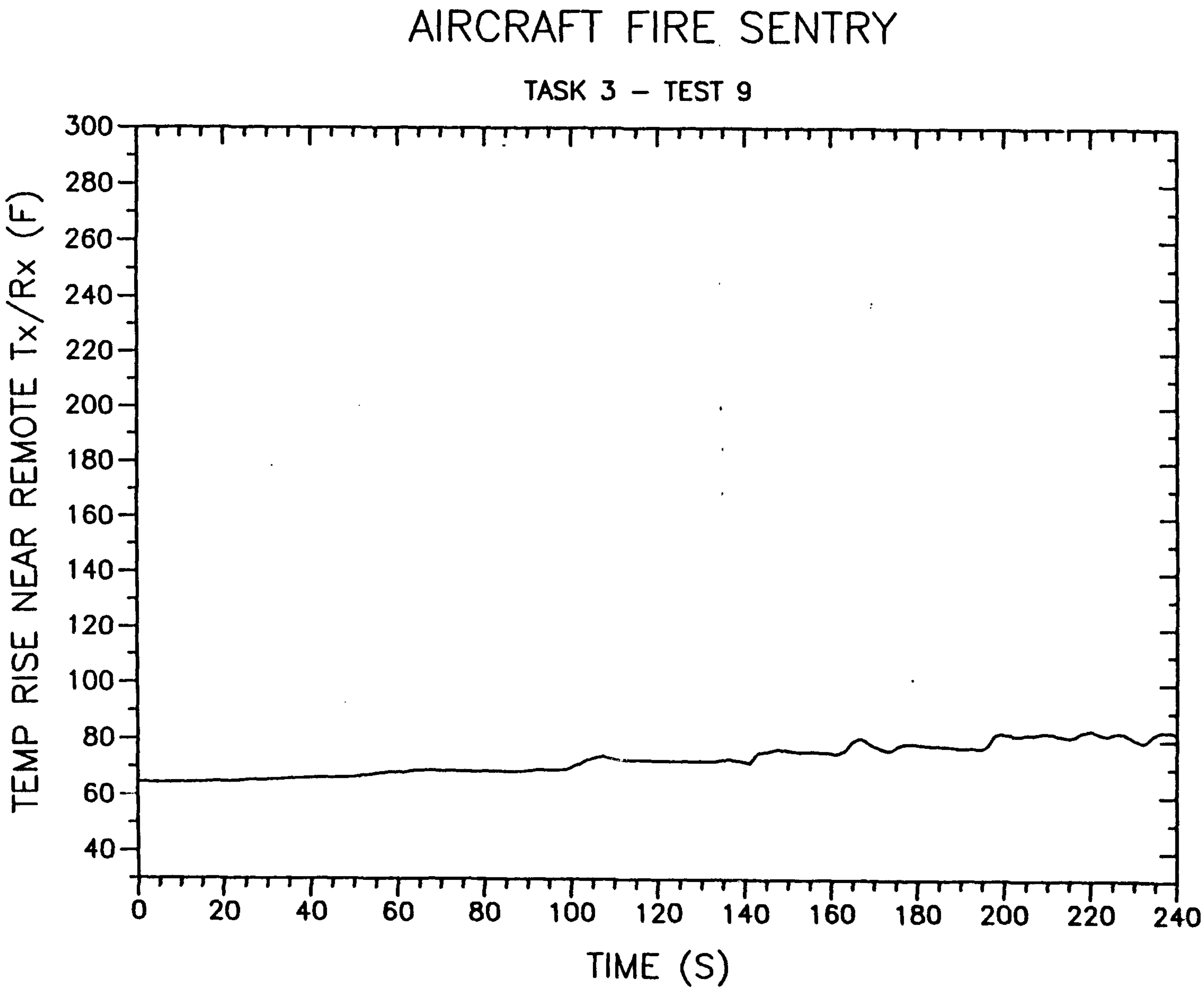

AIRCRAFT FIRE SENTRY
TASK 3 - TEST 9
TEST DURATION MARKER
TEST RUNS FULL DURATION (4 MIN.) - NO ALARM
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)


AIRCRAFT FIRE SENTRY
TASK 3 - TEST 9
TIME (S)
SMOKE OBSCURATION NEAR SMOKE DET.
(% / ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
0
1
2
3
4
5
6
7
8
9
10

AIRCRAFT FIRE SENTRY

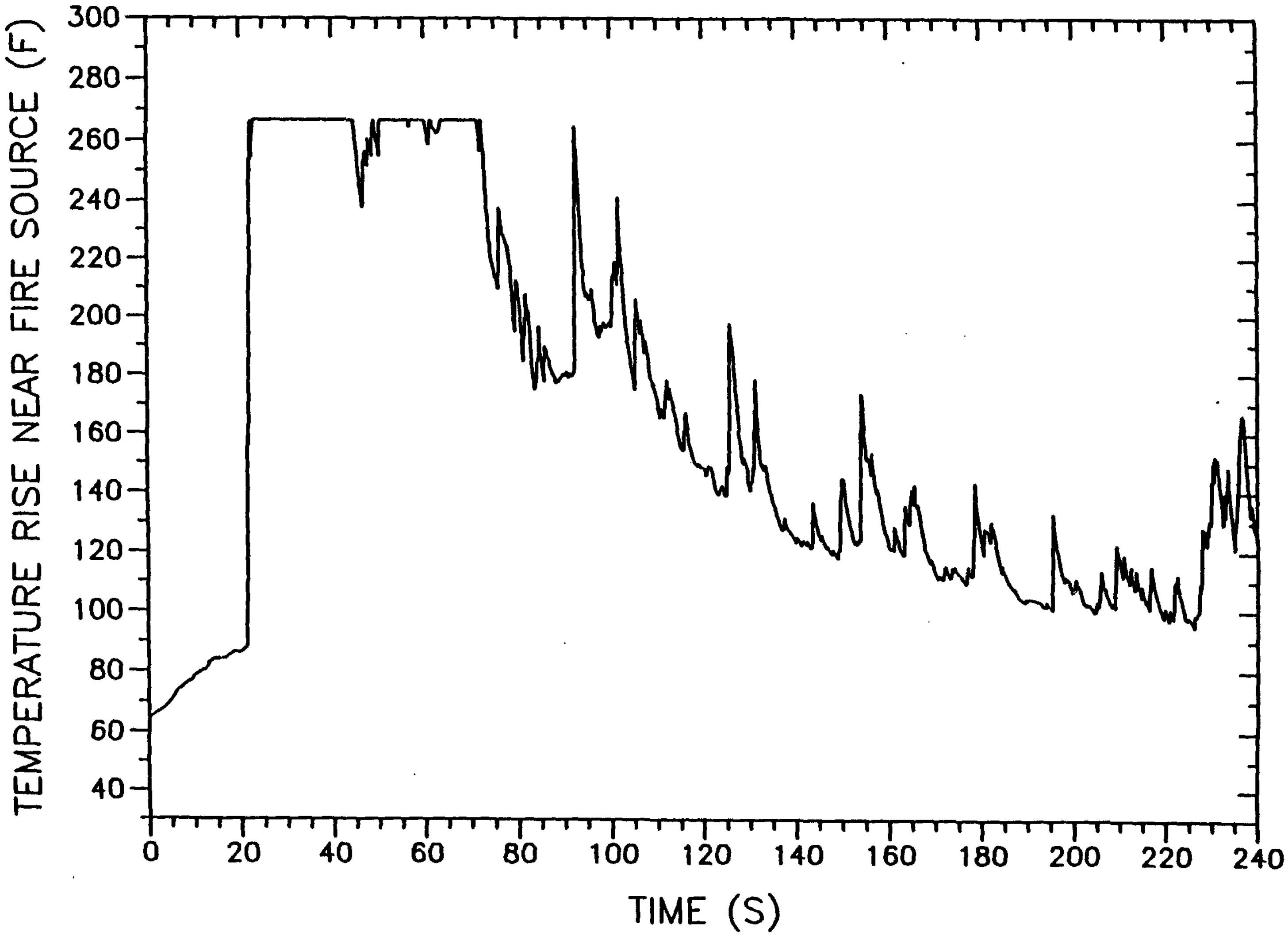
TASK 3 - TEST 9

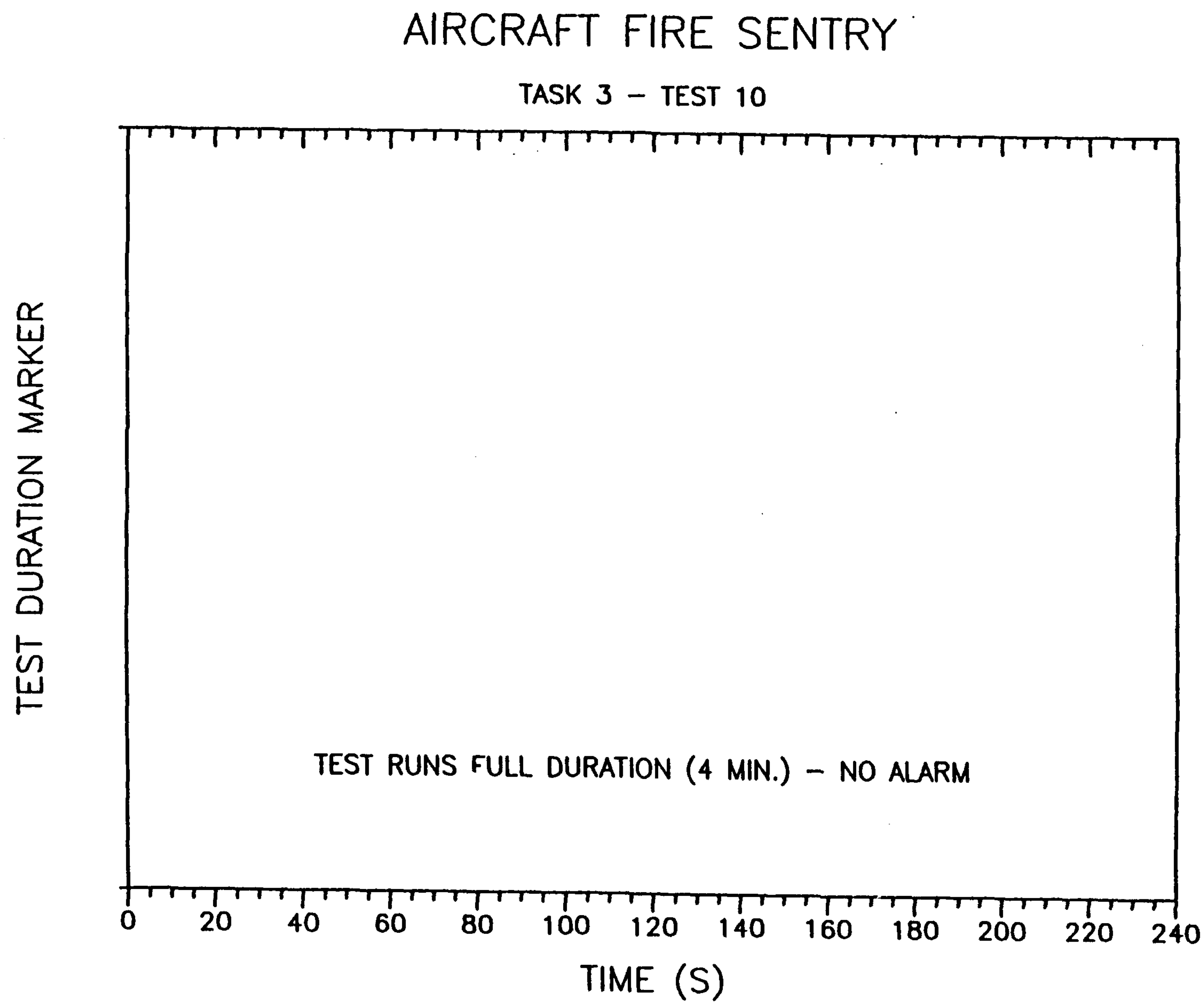



AIRCRAFT FIRE SENTRY
TASK 3 – TEST 9
TEMP RISE NEAR REMOTE Tx/Rx (F)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)

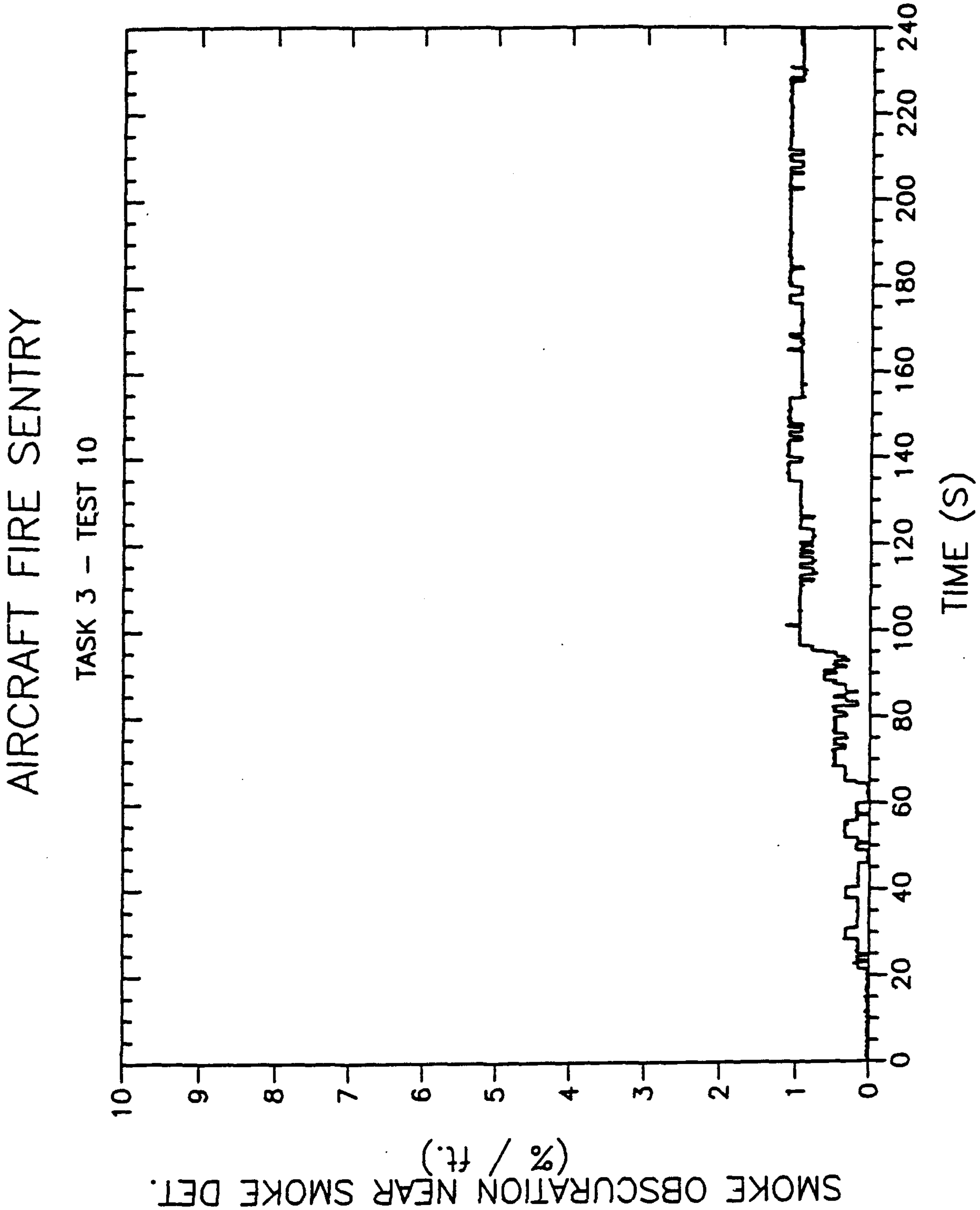
AIRCRAFT FIRE SENTRY

TASK 3 – TEST 9



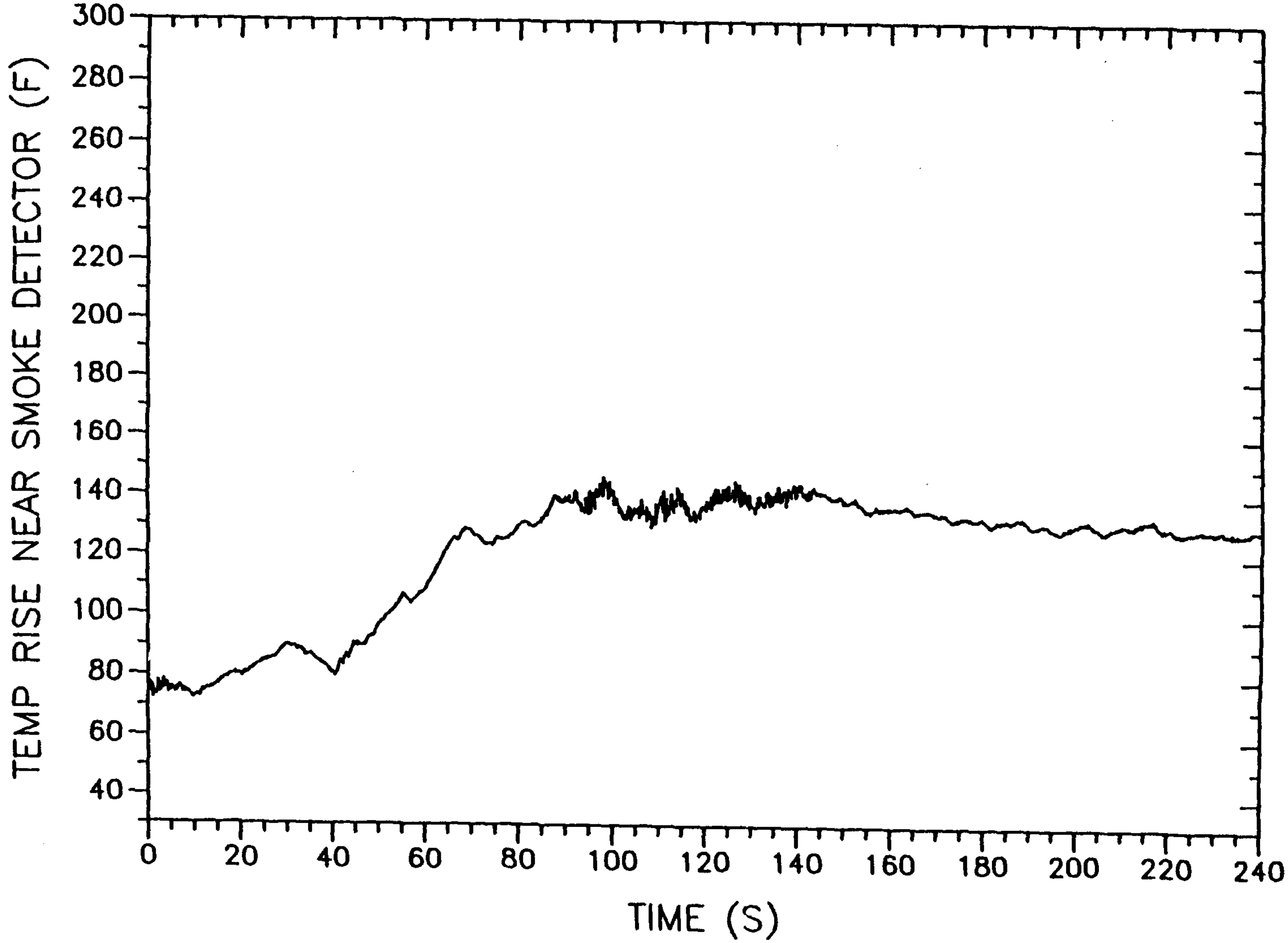


AIRCRAFT FIRE SENTRY
TASK 3 - TEST 10
TEST DURATION MARKER
TEST RUNS FULL DURATION (4 MIN.) - NO ALARM
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)


AIRCRAFT FIRE SENTRY
TASK 3 – TEST 10
SMOKE OBSCURATION NEAR SMOKE DET.
(% / ft.)
TIME (S)
0 1 2 3 4 5 6 7 8 9 10
0 20 40 60 80 100 120 140 160 180 200 220 240

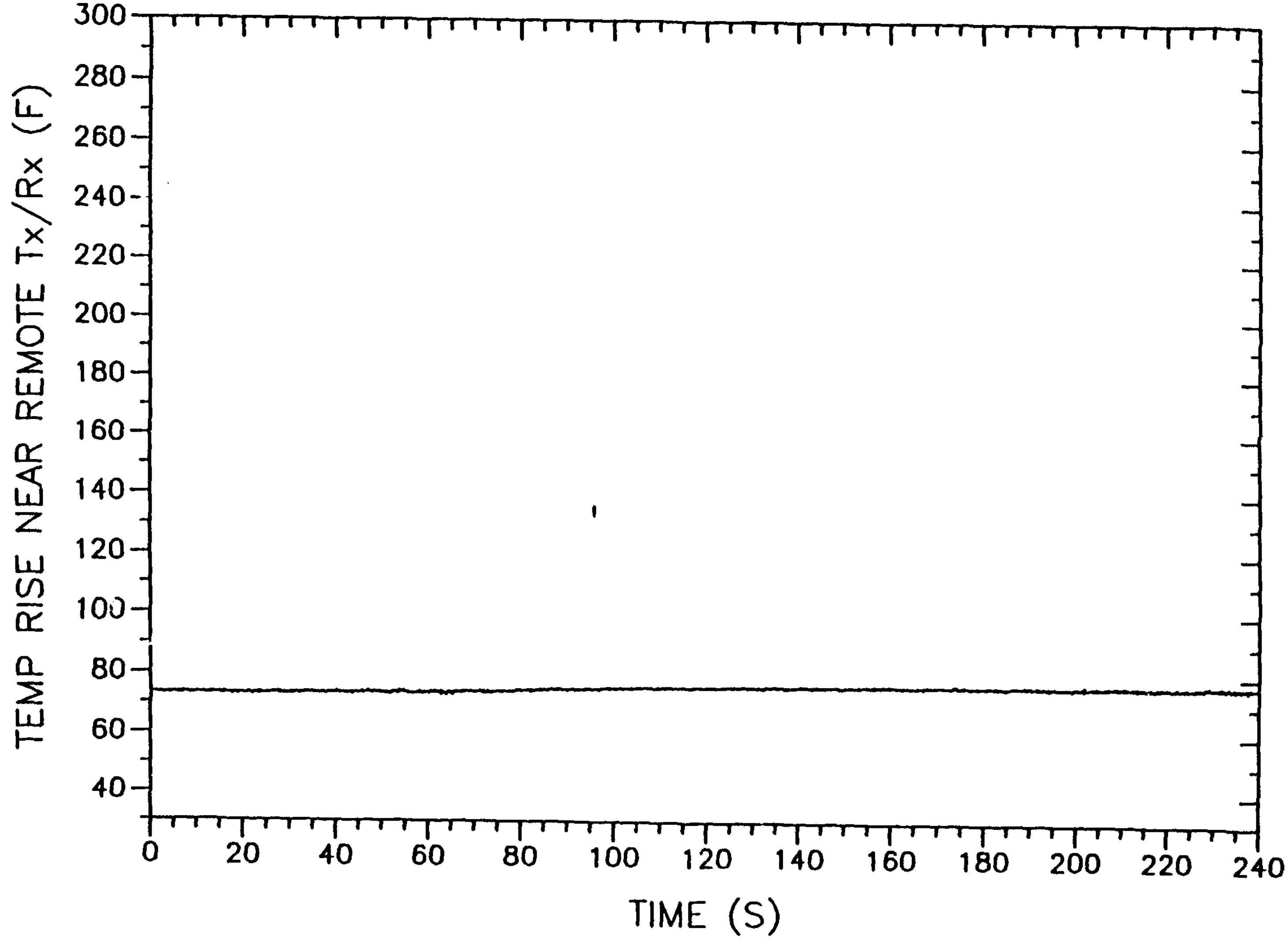
AIRCRAFT FIRE SENTRY

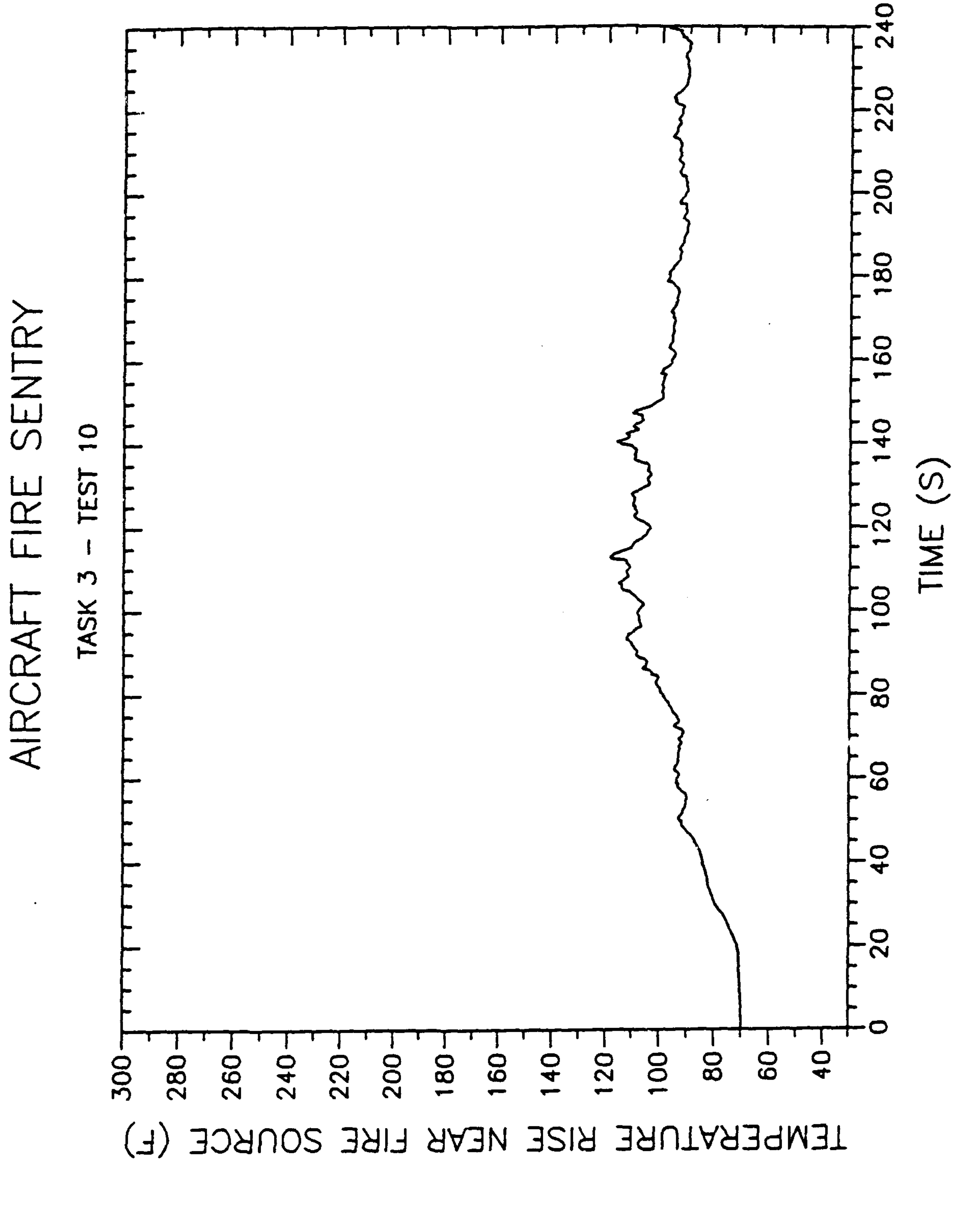
TASK 3 - TEST 10



AIRCRAFT FIRE SENTRY

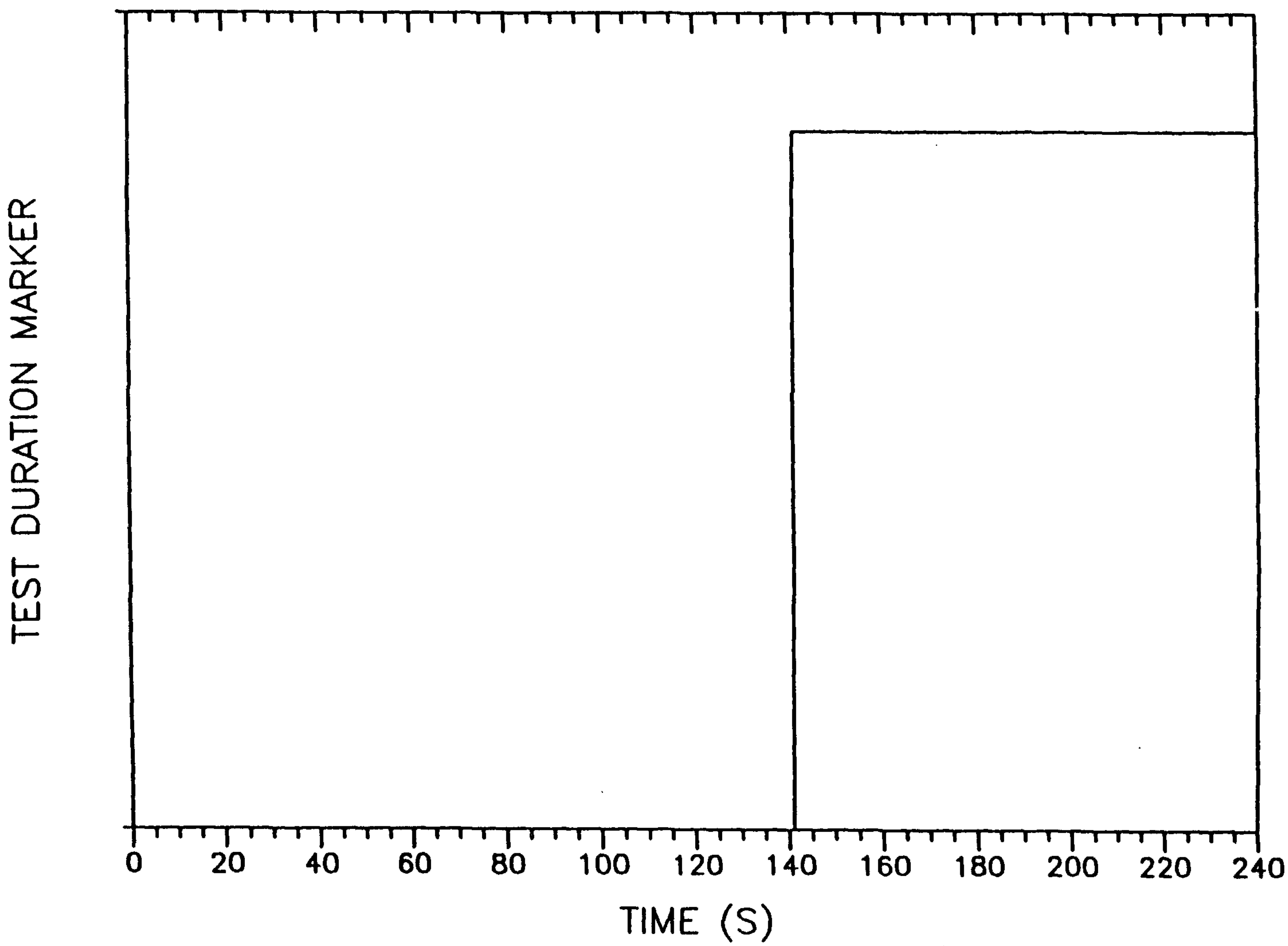
TASK 3 – TEST 10

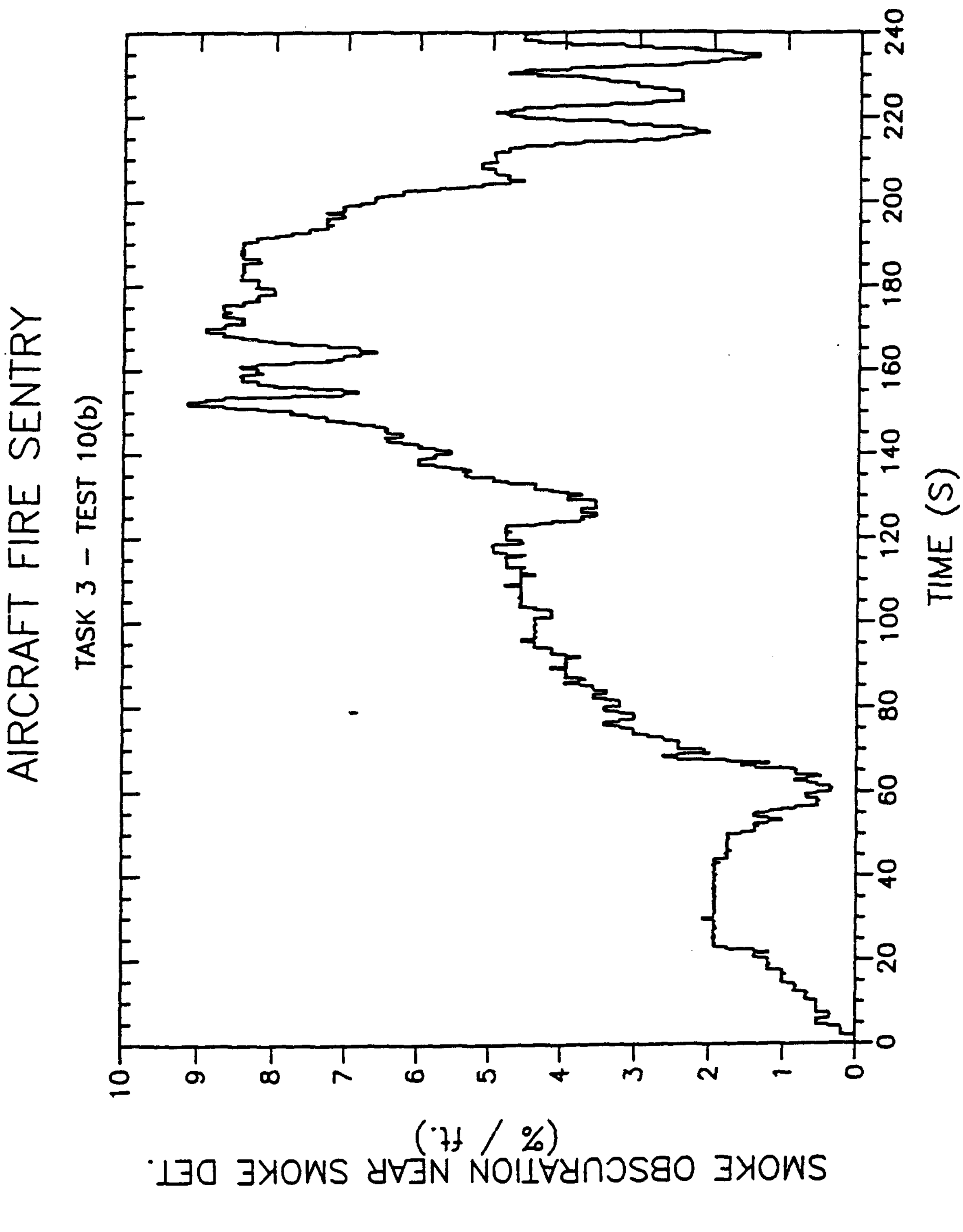



AIRCRAFT FIRE SENTRY
TASK 3 - TEST 10
TEMPERATURE RISE NEAR FIRE SOURCE (F)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)

AIRCRAFT FIRE SENTRY

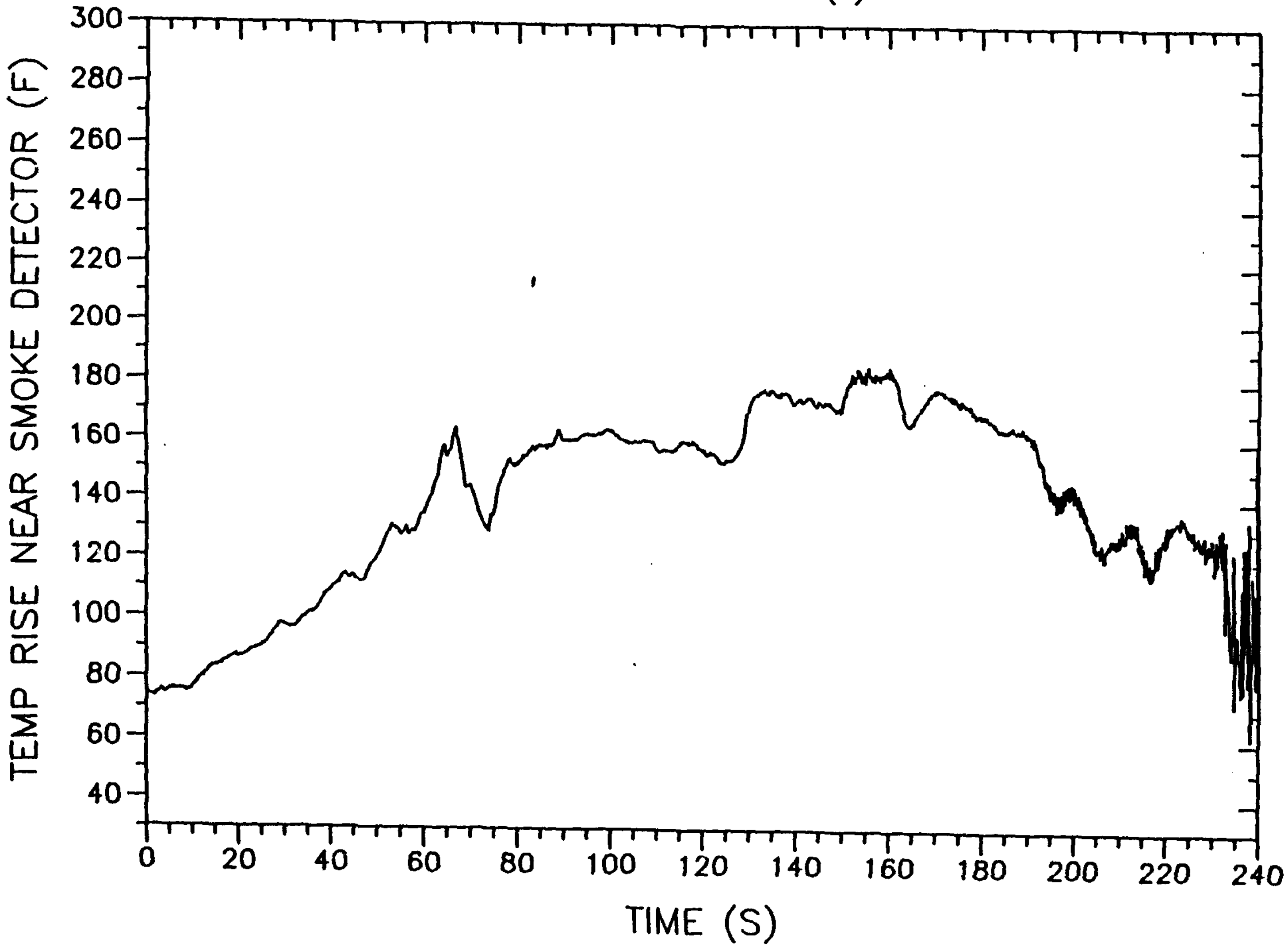
TASK 3 – TEST 10(b)

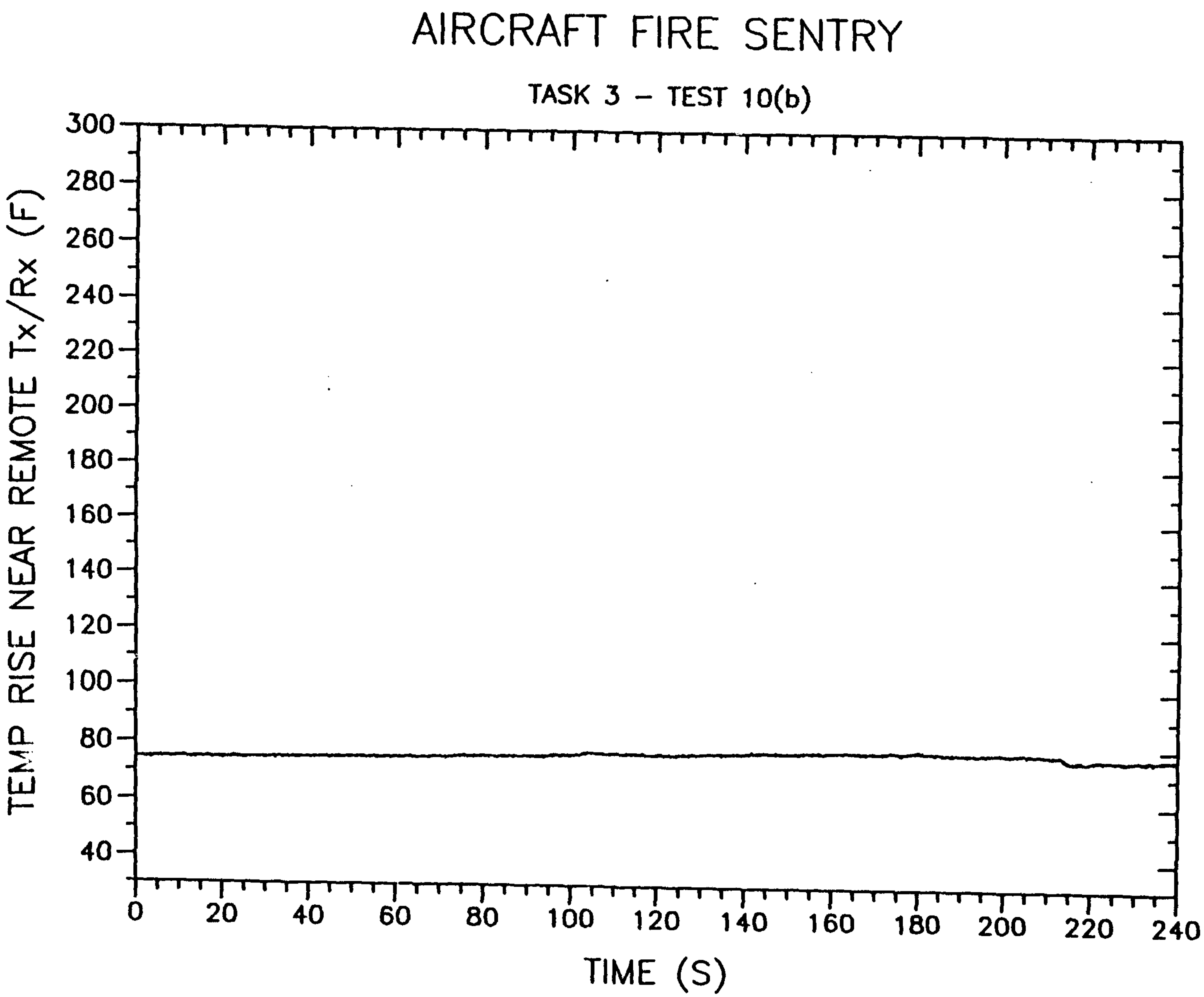


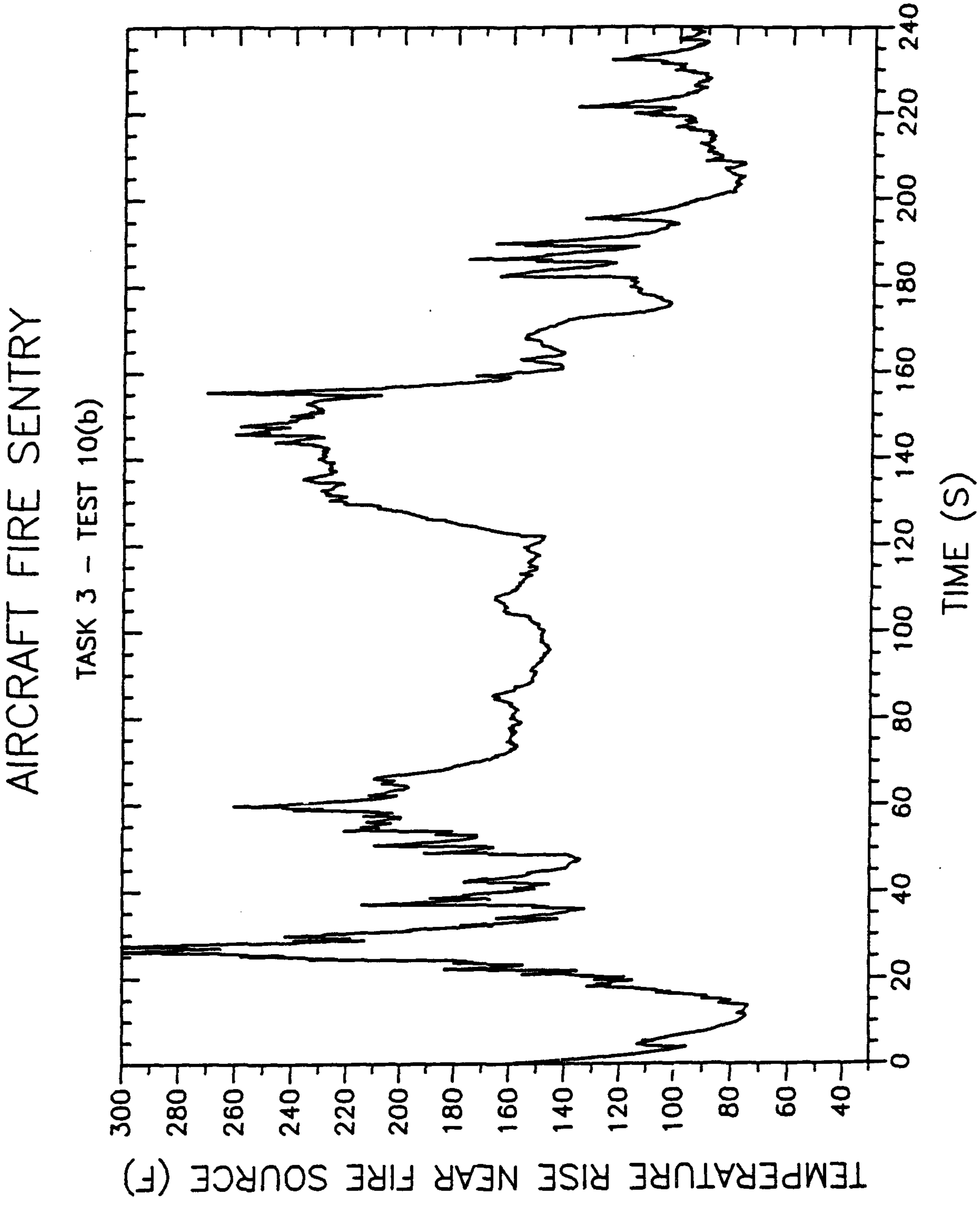

AIRCRAFT FIRE SENTRY
TASK 3 - TEST 10(b)
SMOKE OBSCURATION NEAR SMOKE DET. (% / ft.)
TIME (S)
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
120
140
160
180
200
220
240

AIRCRAFT FIRE SENTRY

TASK 3 – TEST 10(b)

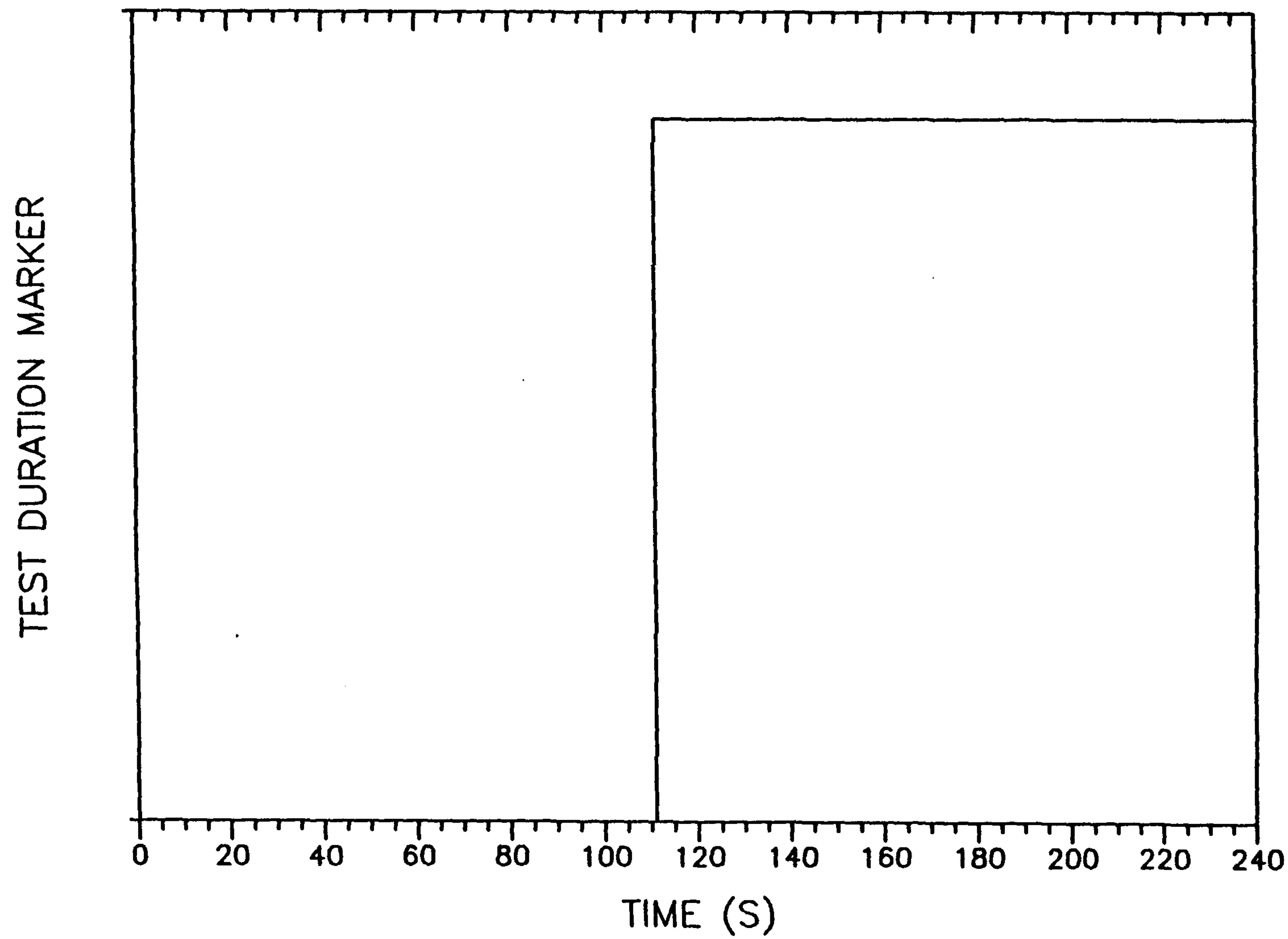



AIRCRAFT FIRE SENTRY
TASK 3 – TEST 10(b)
TEMP RISE NEAR REMOTE Tx/Rx (F)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)


AIRCRAFT FIRE SENTRY
TASK 3 - TEST 10(b)
TEMPERATURE RISE NEAR FIRE SOURCE (F)
TIME (S)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240

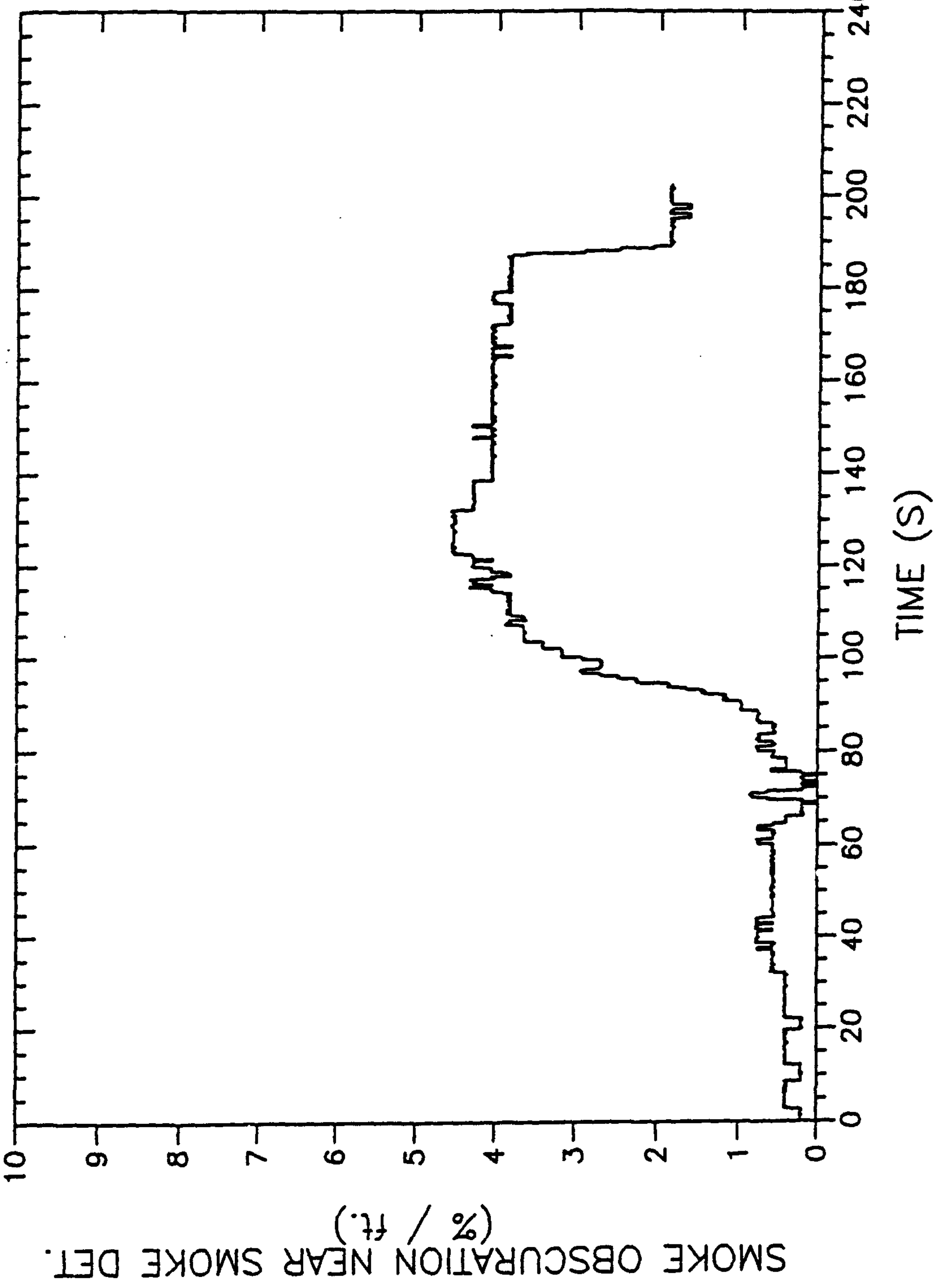
AIRCRAFT FIRE SENTRY

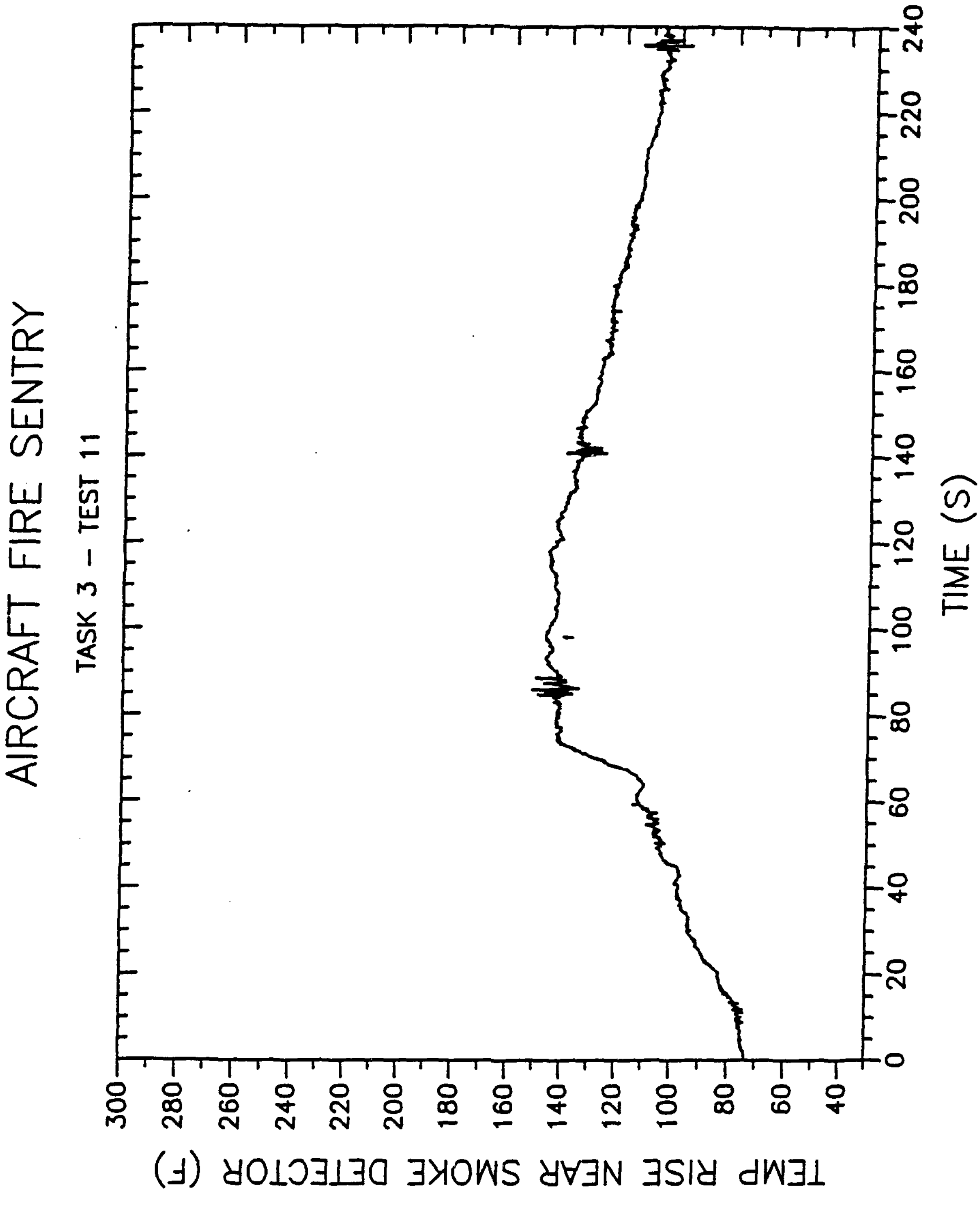
TASK 3 – TEST 11

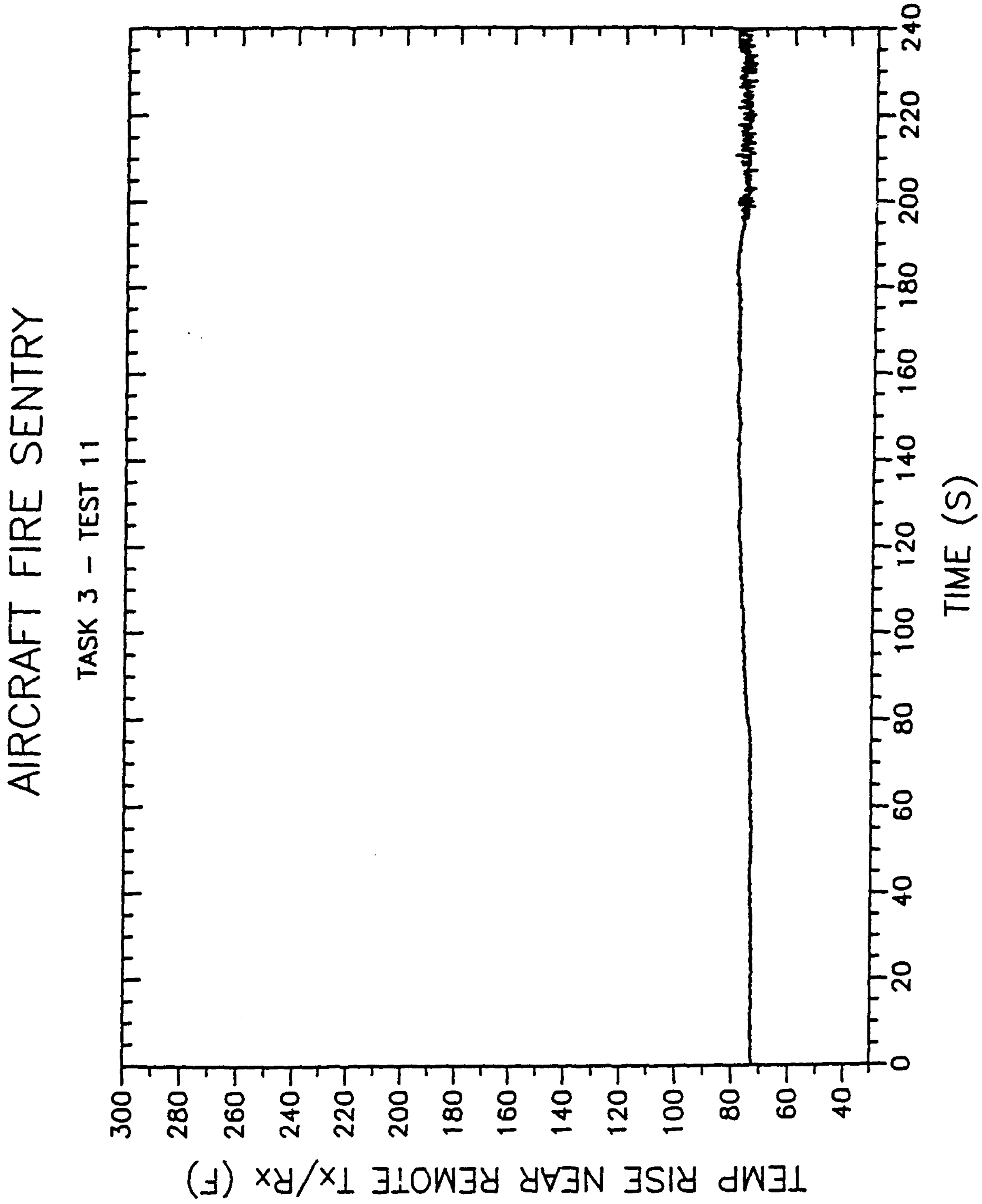


AIRCRAFT FIRE SENTRY

TASK 3 - TEST 11

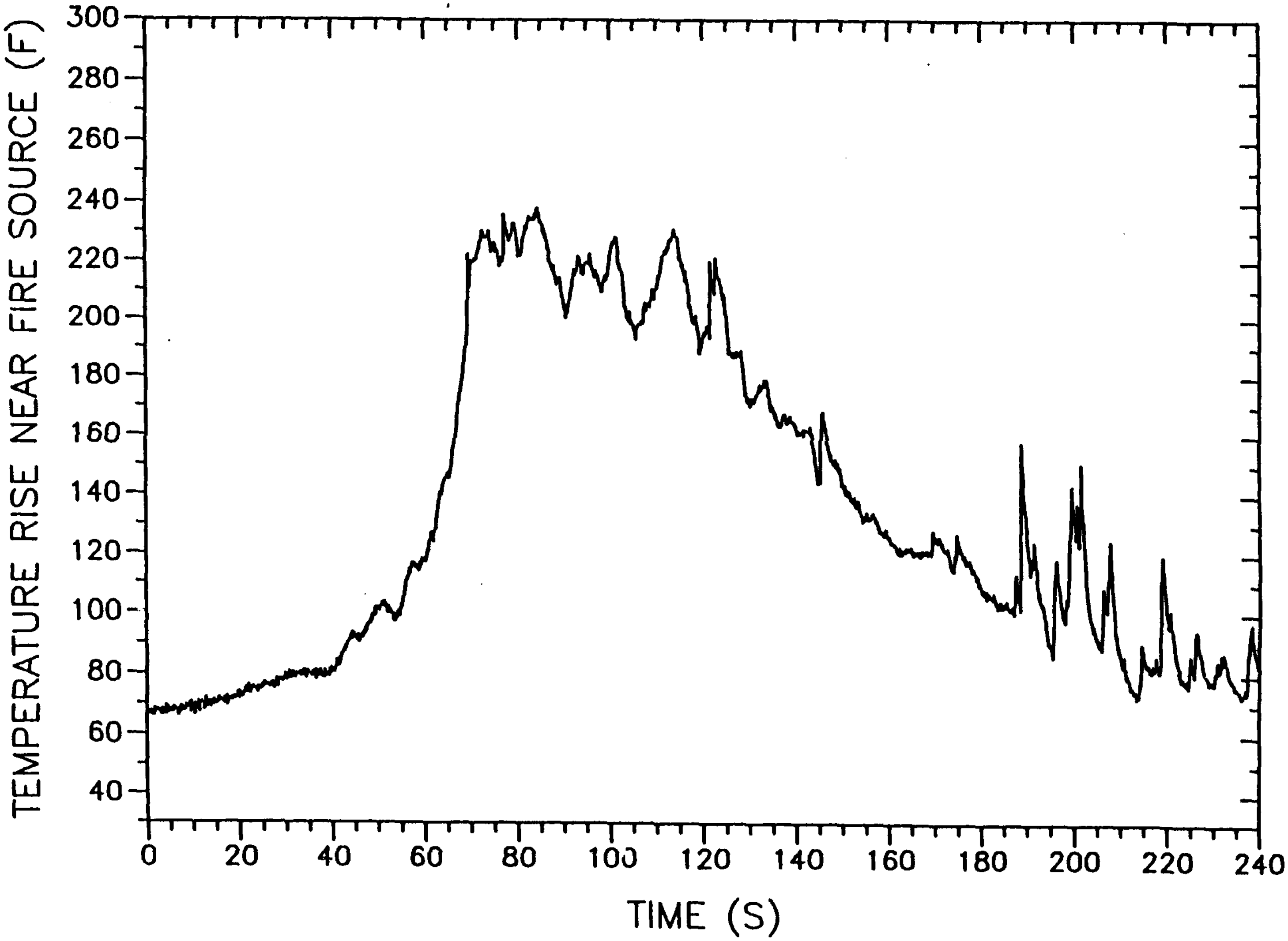



AIRCRAFT FIRE SENTRY
TASK 3 – TEST 11
TEMP RISE NEAR SMOKE DETECTOR (F)
TIME (S)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
TASK 3 – TEST 11
TEMP RISE NEAR REMOTE Tx/Rx (F)
TIME (S)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240

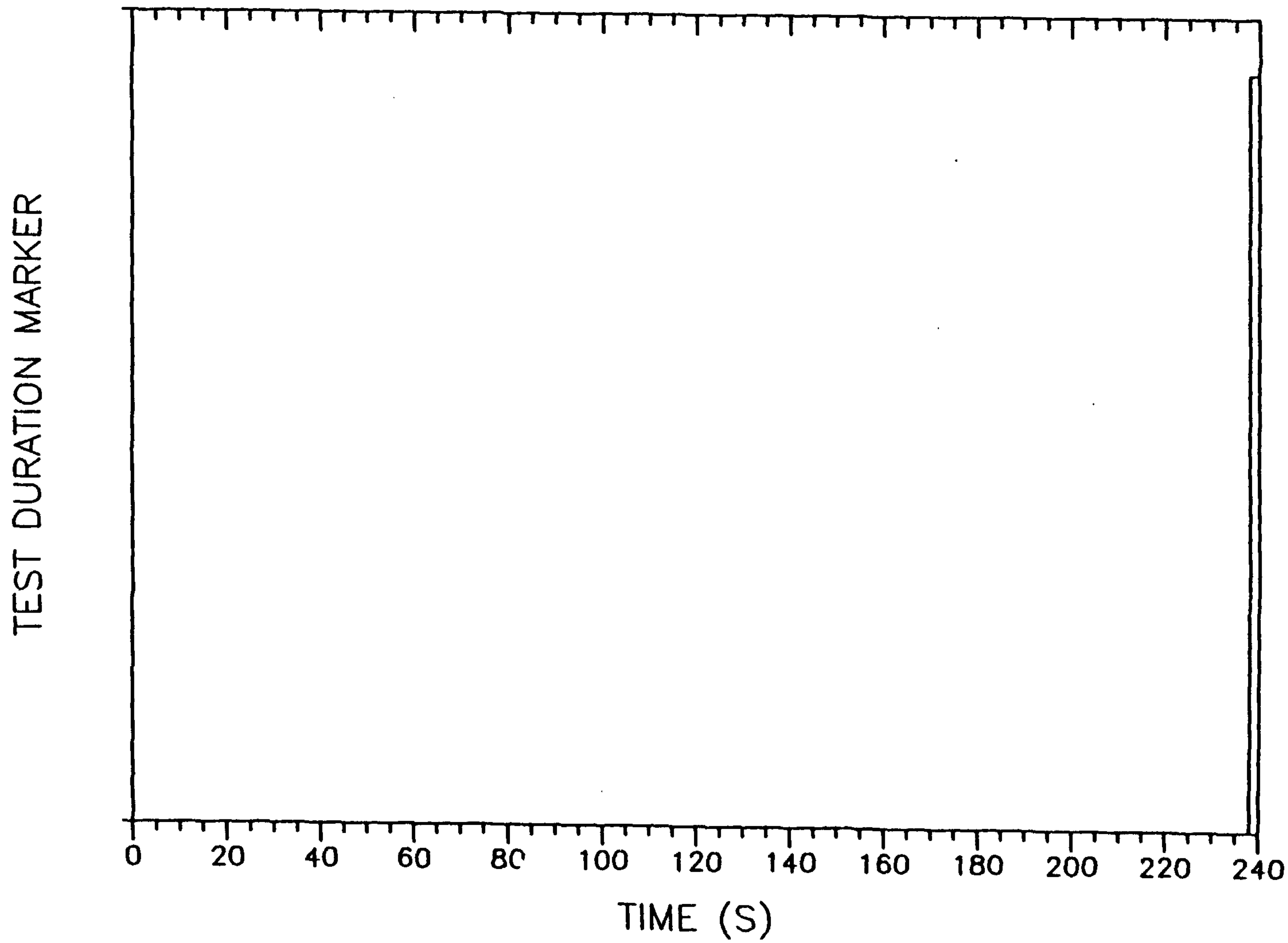
AIRCRAFT FIRE SENTRY

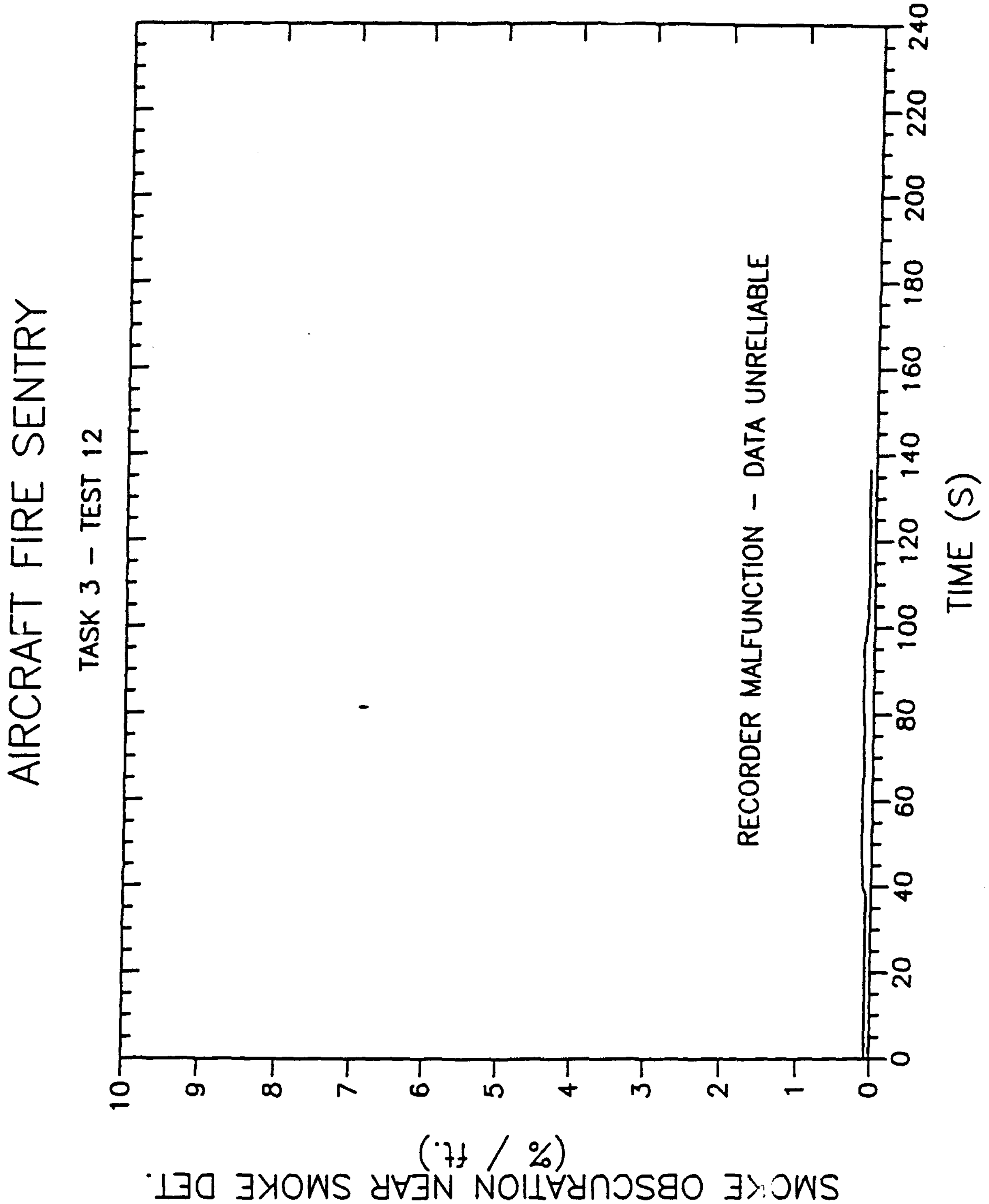
TASK 3 – TEST 11

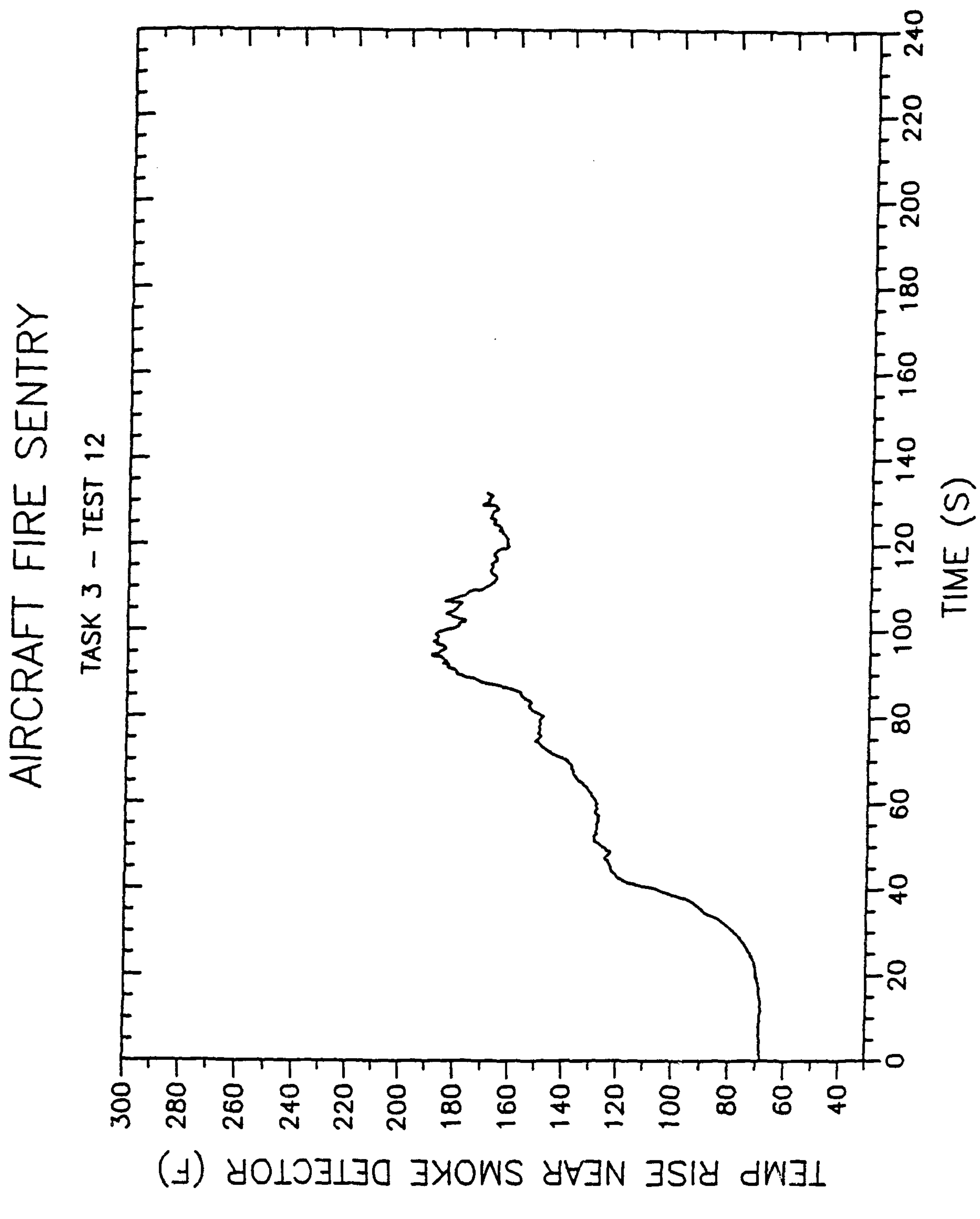


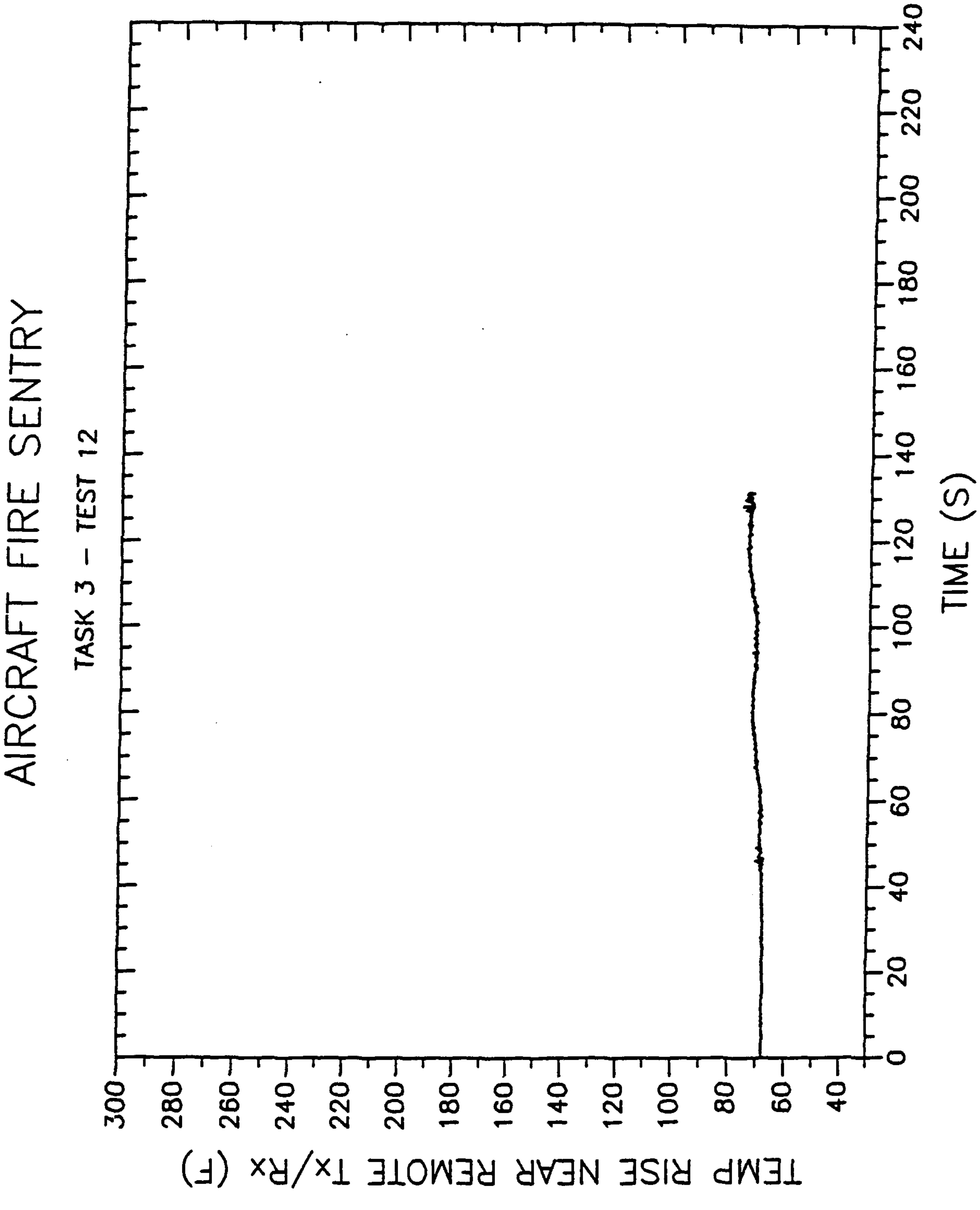
AIRCRAFT FIRE SENTRY

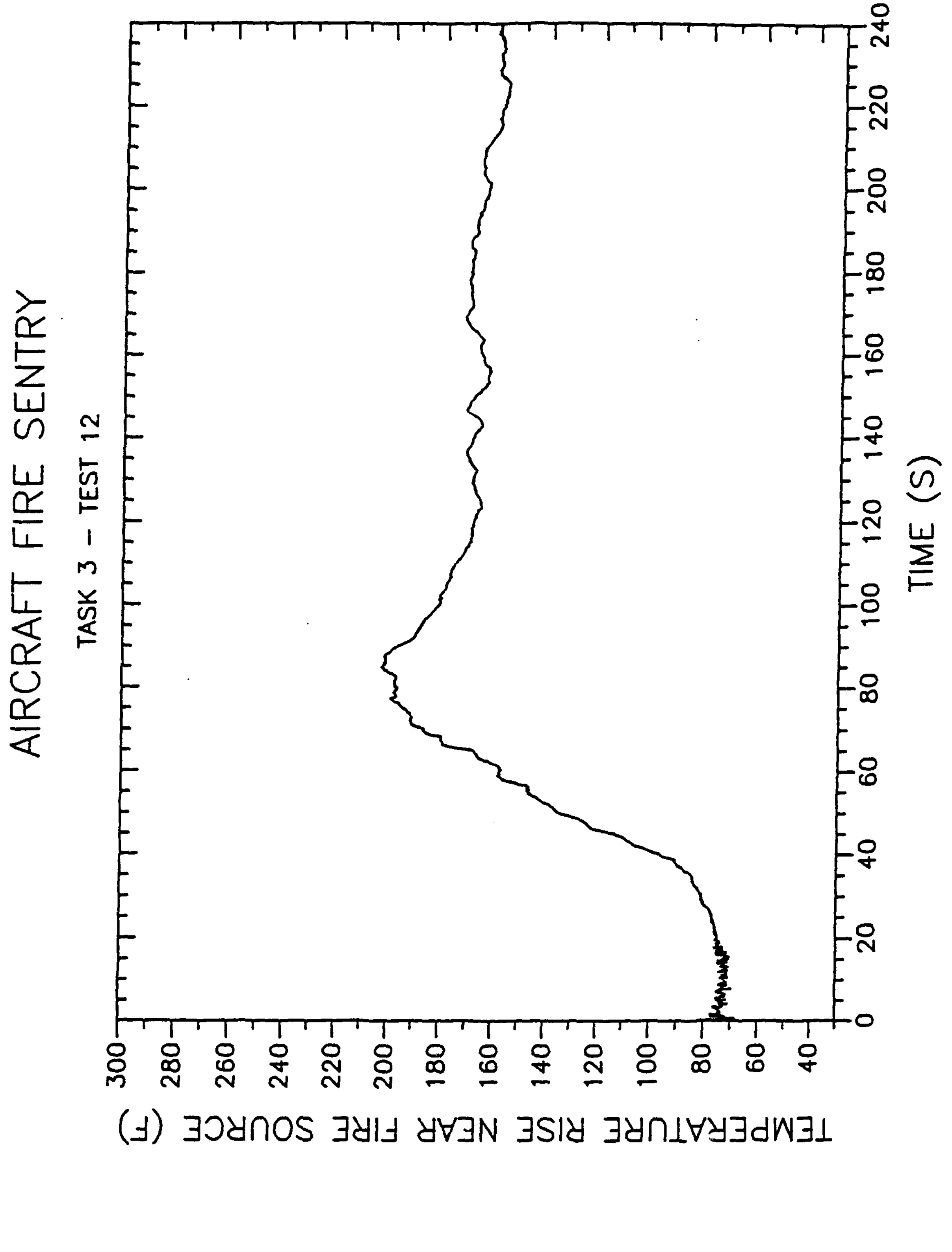
TASK 3 – TEST 12




AIRCRAFT FIRE SENTRY
TASK 3 – TEST 12
RECORDER MALFUNCTION – DATA UNRELIABLE
SMOKE OBSCURATION NEAR SMOKE DET.
(% / ft.)
0
1
2
3
4
5
6
7
8
9
10
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240

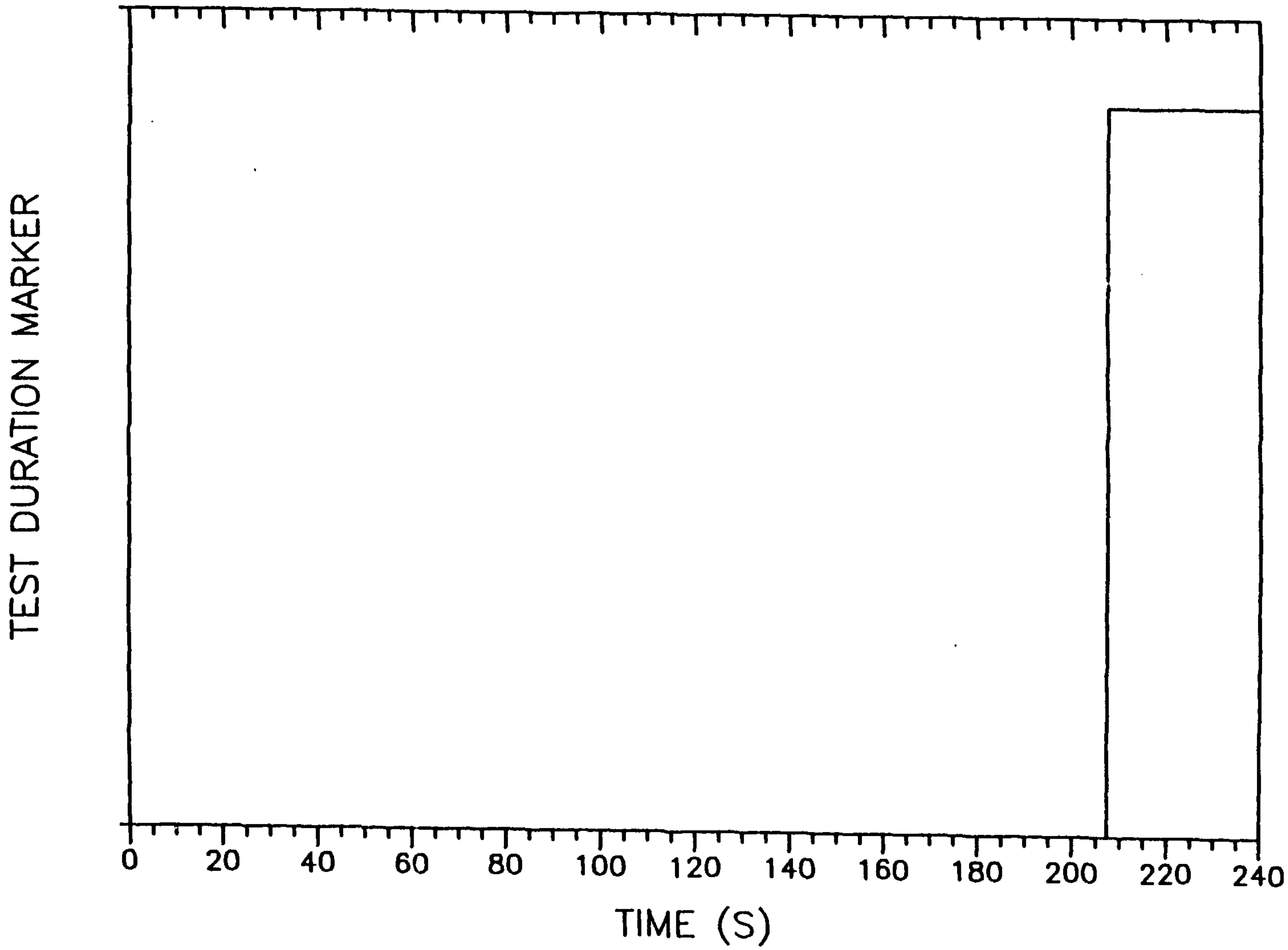

AIRCRAFT FIRE SENTRY
TASK 3 – TEST 12
TEMP RISE NEAR SMOKE DETECTOR (F)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240

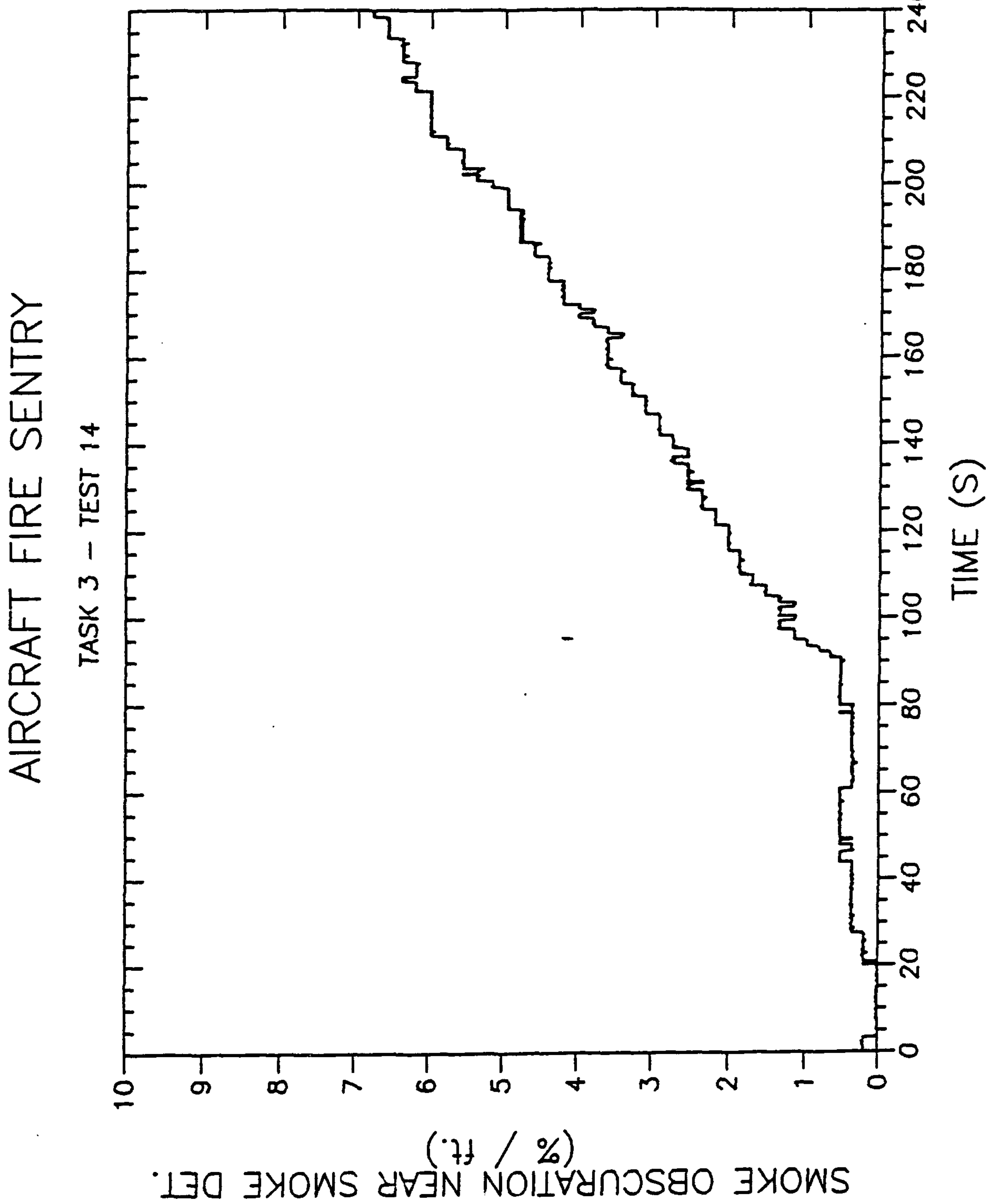

AIRCRAFT FIRE SENTRY
TASK 3 – TEST 12
TEMP RISE NEAR REMOTE Tx/Rx (F)
TIME (S)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240

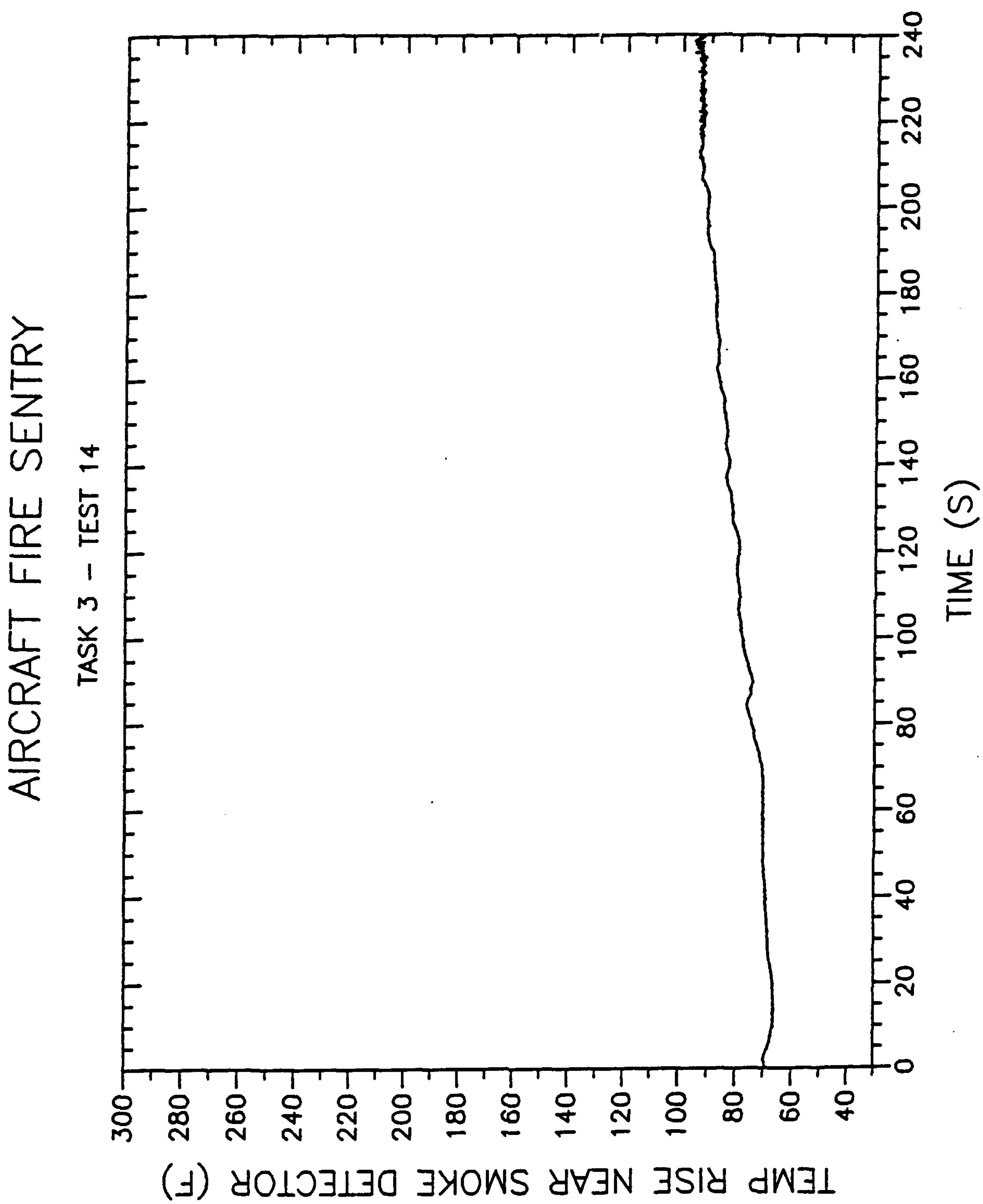

AIRCRAFT FIRE SENTRY
TASK 3 – TEST 12
TEMPERATURE RISE NEAR FIRE SOURCE (F)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240

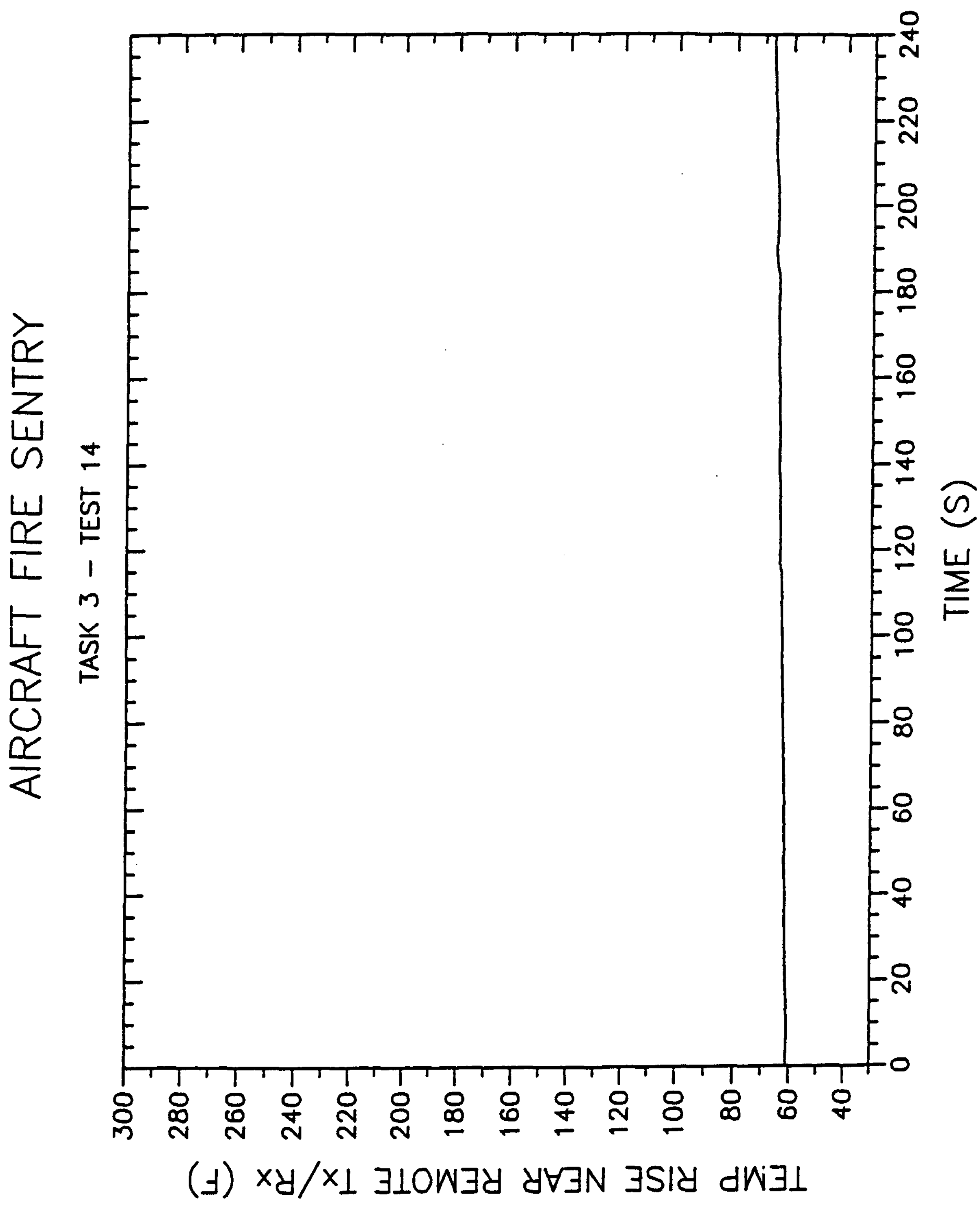
AIRCRAFT FIRE SENTRY

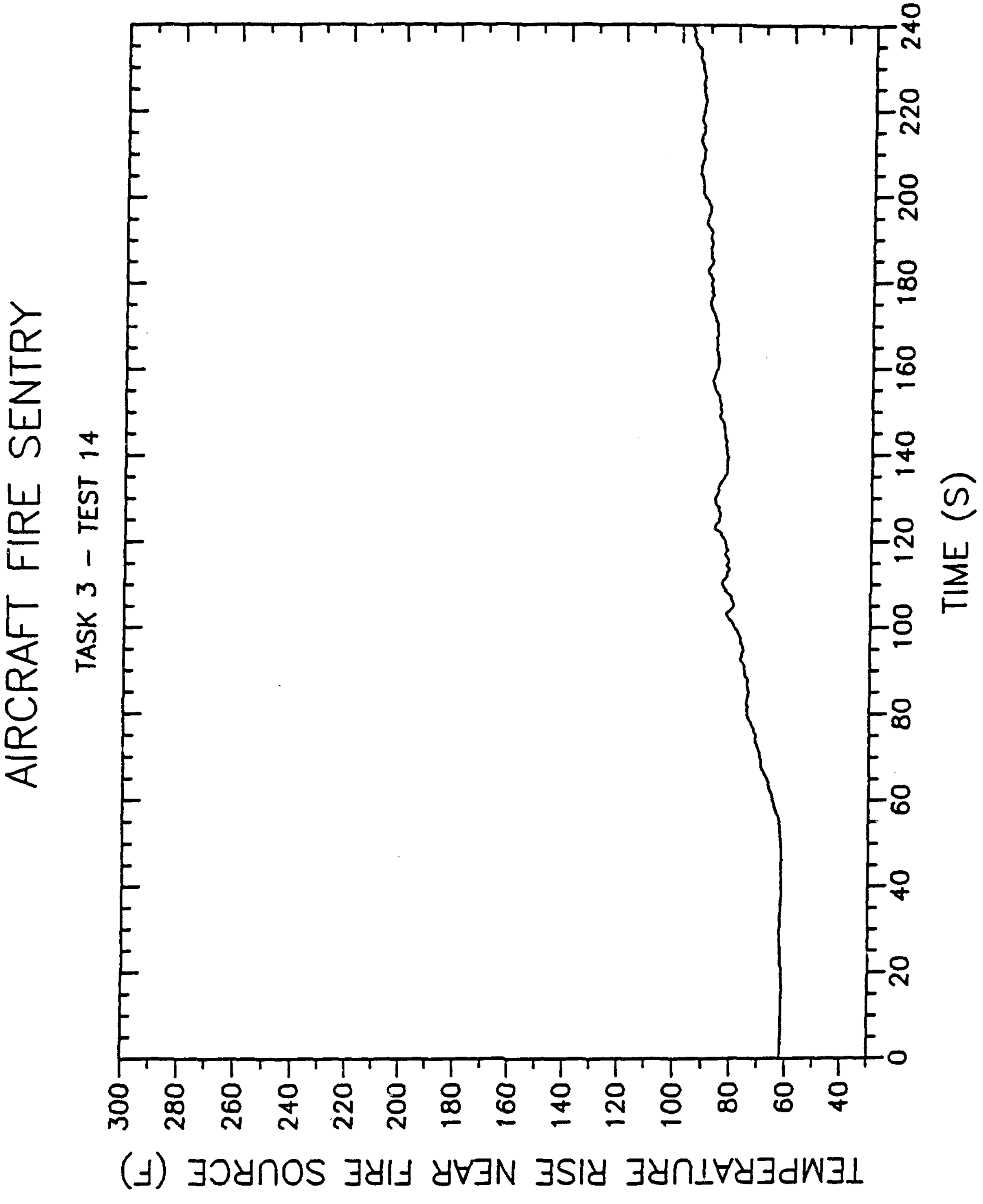
TASK 3 – TEST 14

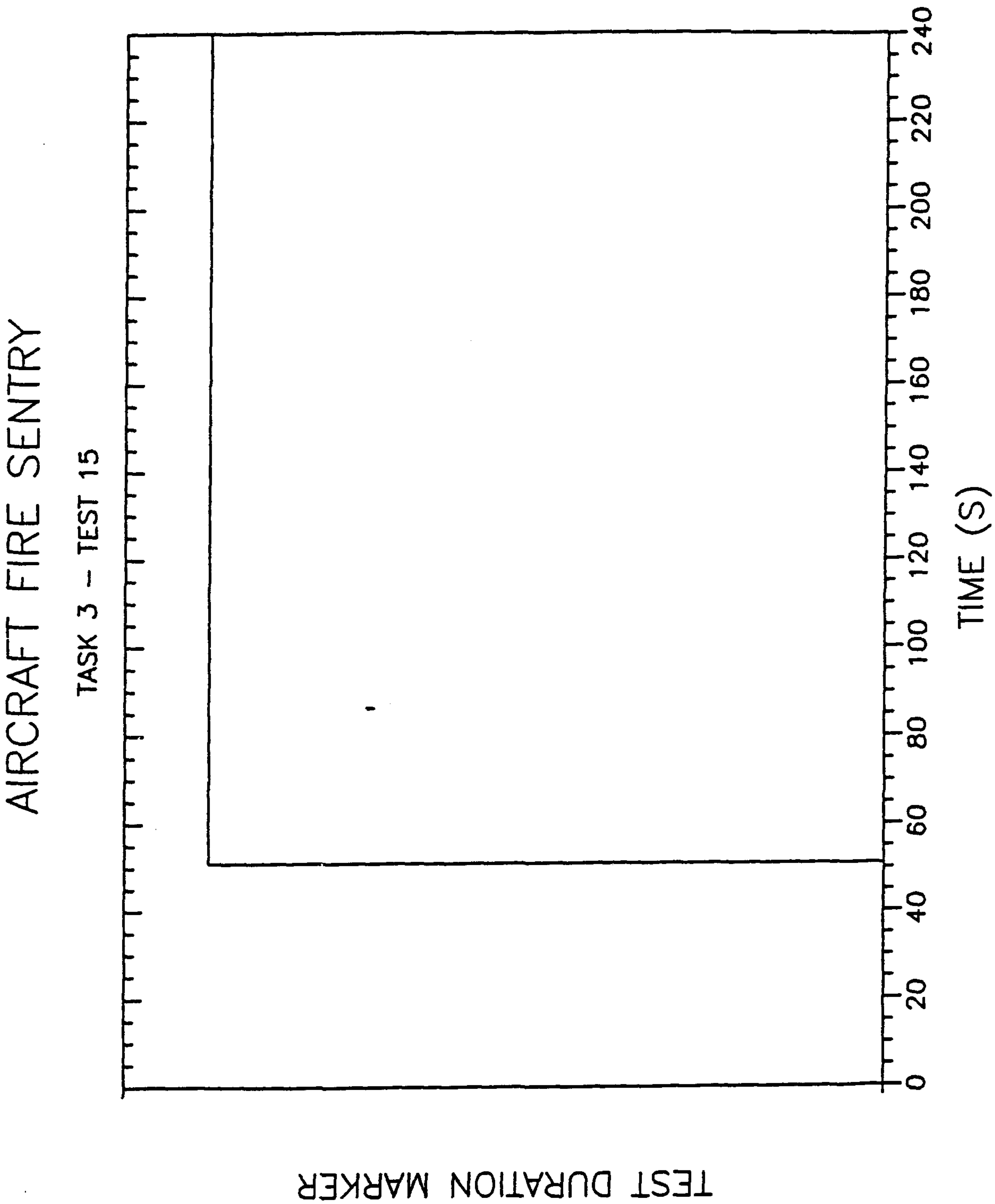


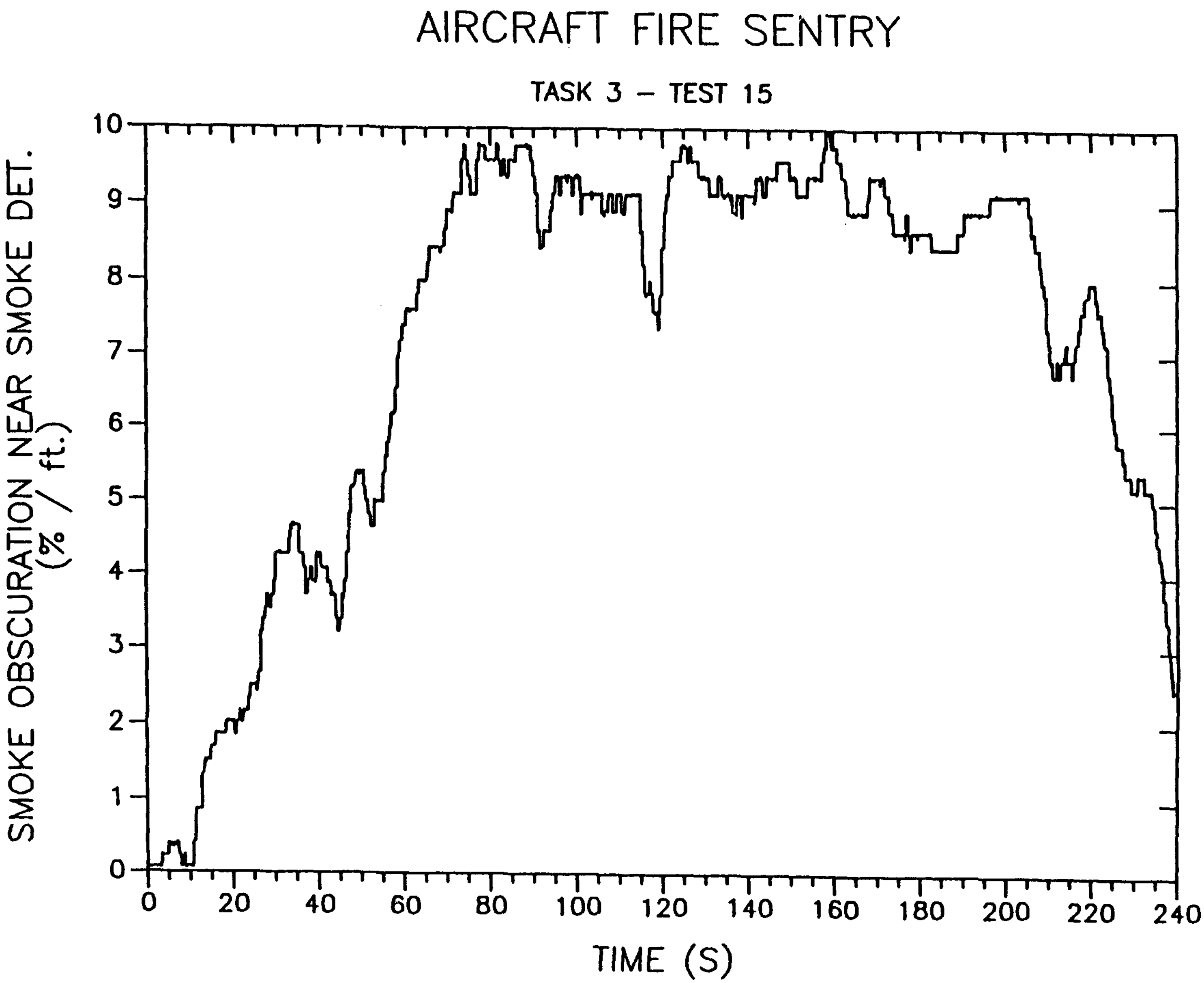

AIRCRAFT FIRE SENTRY
TASK 3 – TEST 14
SMOKE OBSCURATION NEAR SMOKE DET. (% / ft.)
TIME (S)
0 1 2 3 4 5 6 7 8 9 10
0 20 40 60 80 100 120 140 160 180 200 220 240

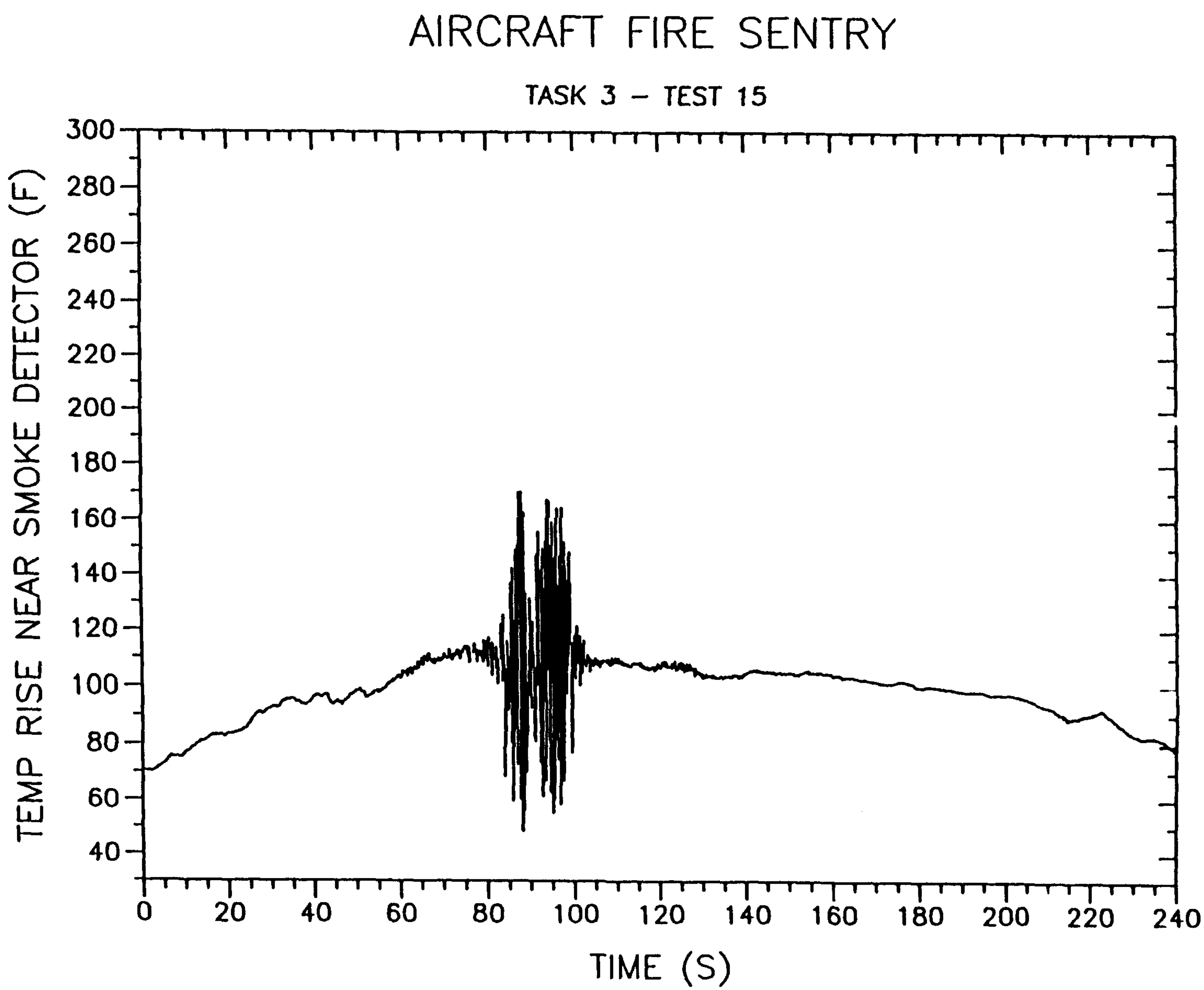

AIRCRAFT FIRE SENTRY
TASK 3 — TEST 14
TEMP RISE NEAR SMOKE DETECTOR (F)
TIME (S)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240

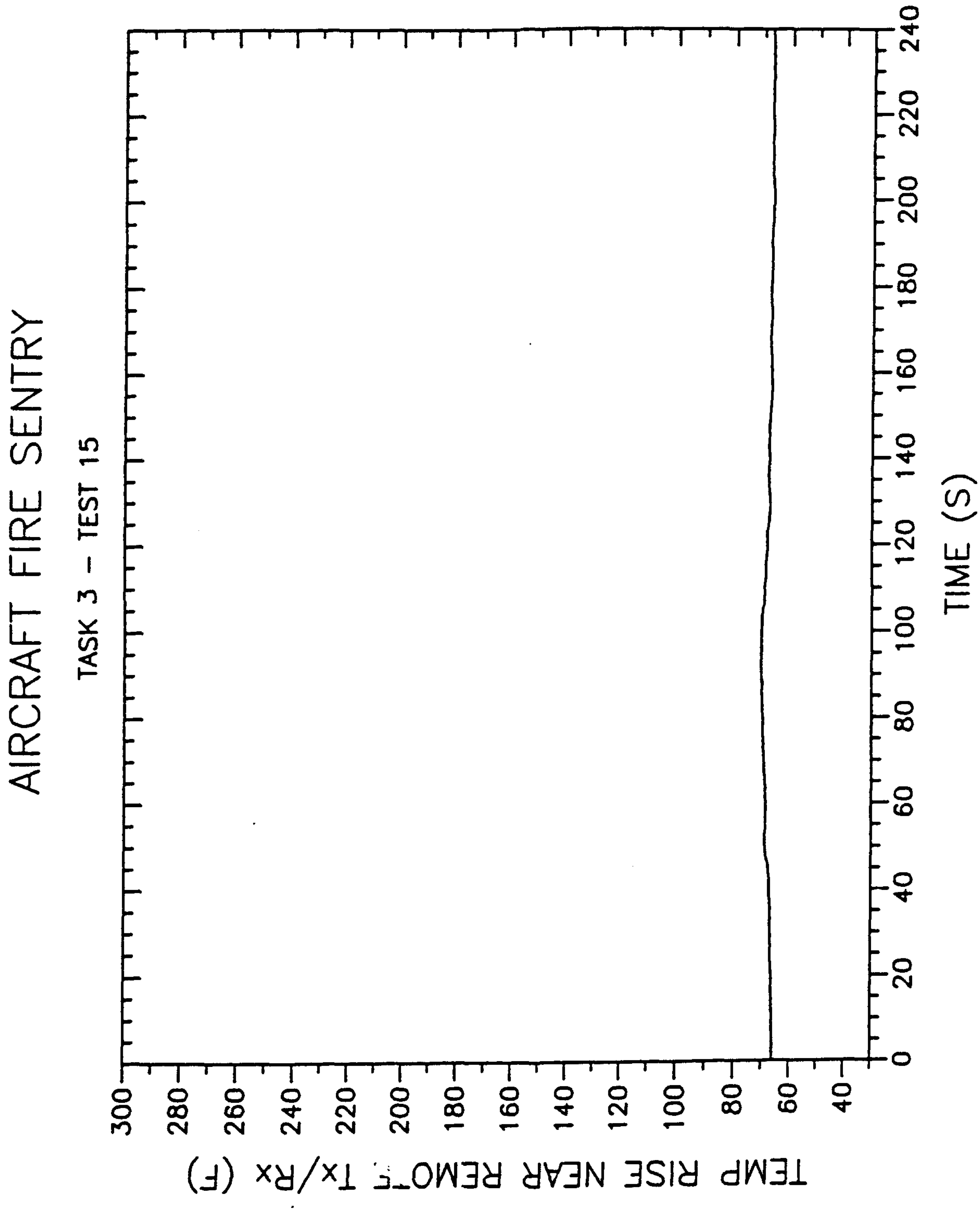

AIRCRAFT FIRE SENTRY
TASK 3 - TEST 14
TEMP RISE NEAR REMOTE Tx/Rx (F)
TIME (S)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
TASK 3 - TEST 14
TEMPERATURE RISE NEAR FIRE SOURCE (F)
TIME (S)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
TASK 3 - TEST 15
TEST DURATION MARKER
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240


AIRCRAFT FIRE SENTRY
TASK 3 – TEST 15
SMOKE OBSCURATION NEAR SMOKE DET. (% / ft.)
TIME (S)
0
1
2
3
4
5
6
7
8
9
10
20
40
60
80
100
120
140
160
180
200
220
240

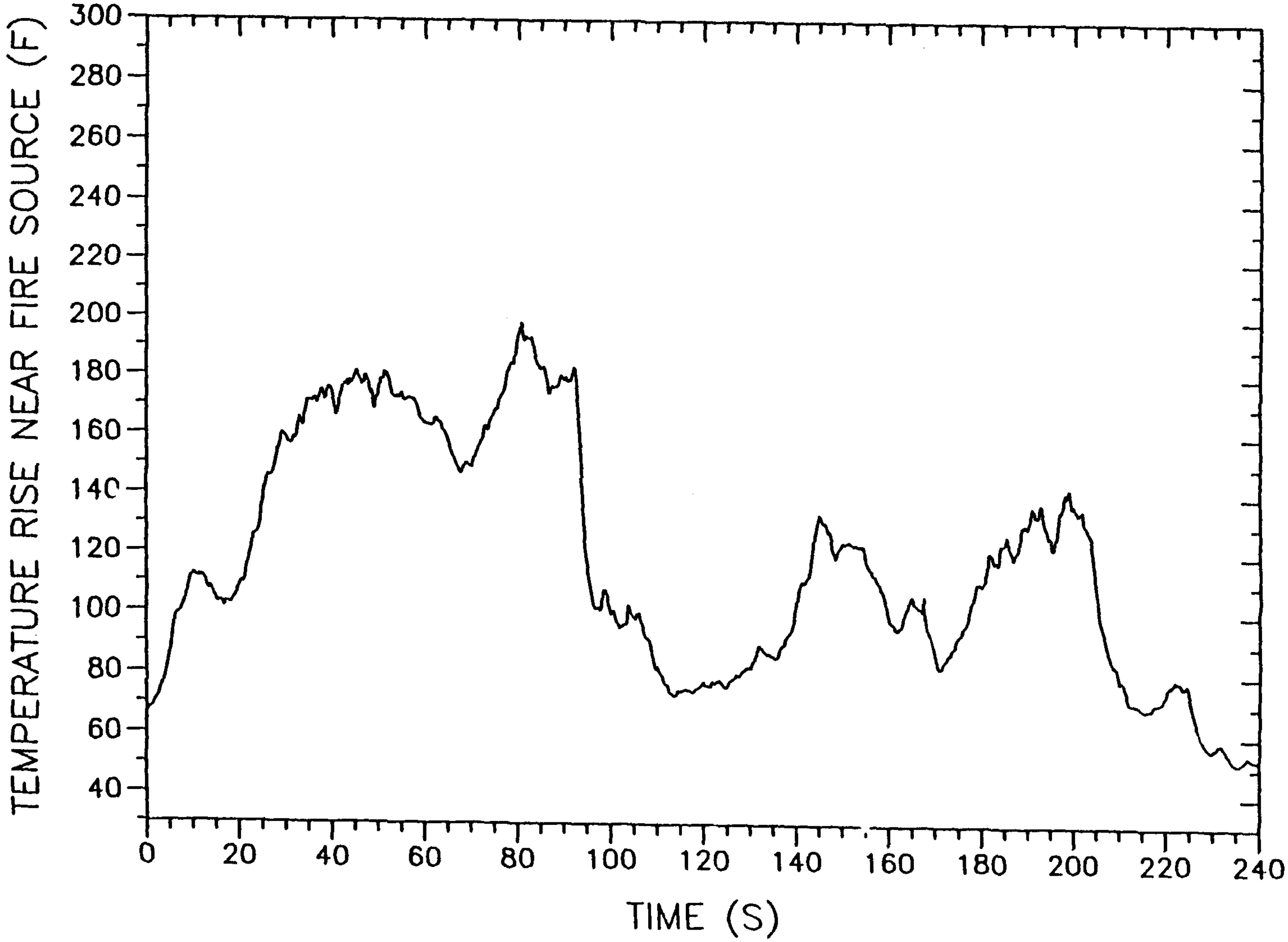

AIRCRAFT FIRE SENTRY
TASK 3 – TEST 15
TEMP RISE NEAR SMOKE DETECTOR (F)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)

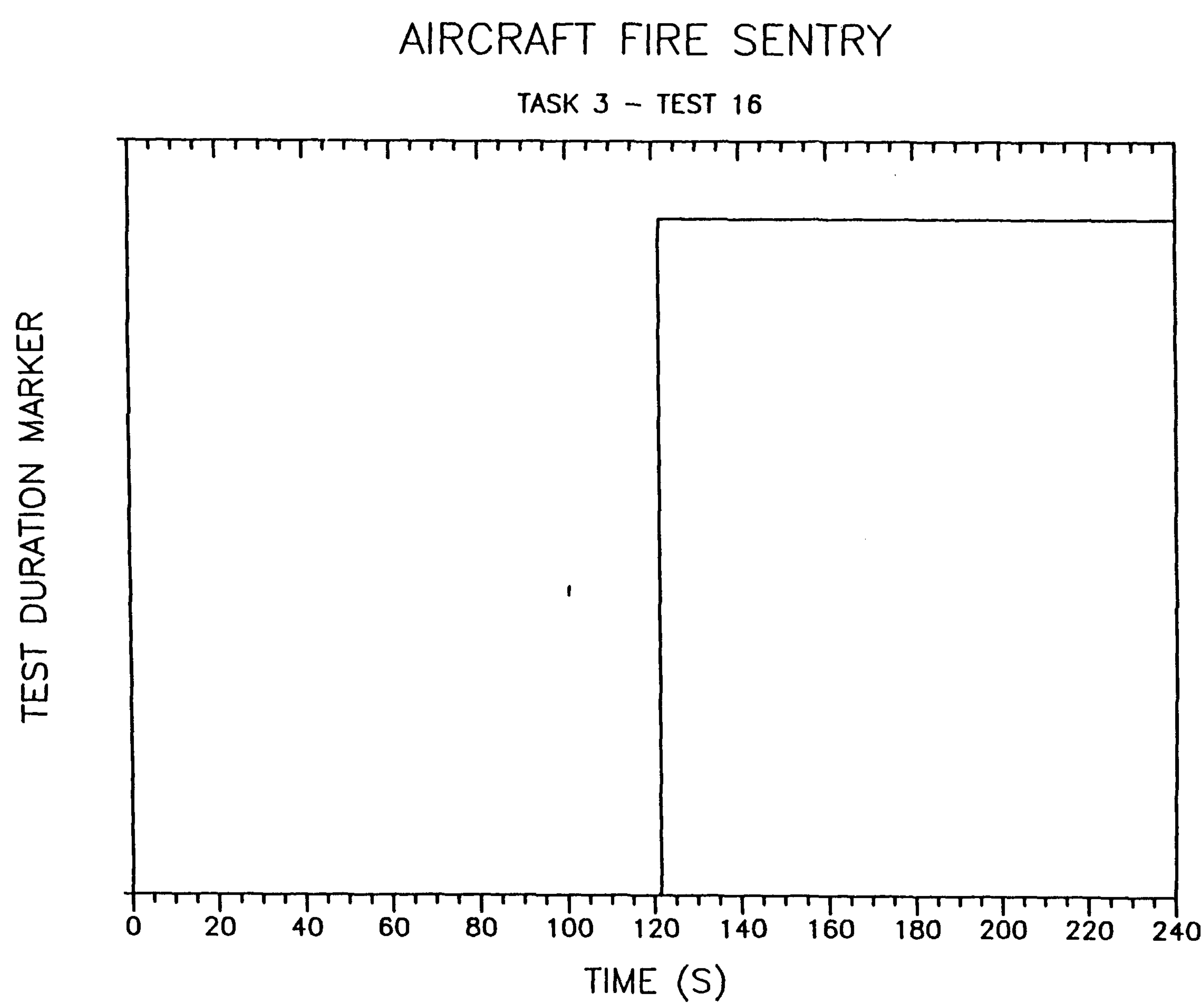


AIRCRAFT FIRE SENTRY
TASK 3 – TEST 15
TEMP RISE NEAR REMOTE Tx/Rx (F)
TIME (S)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240

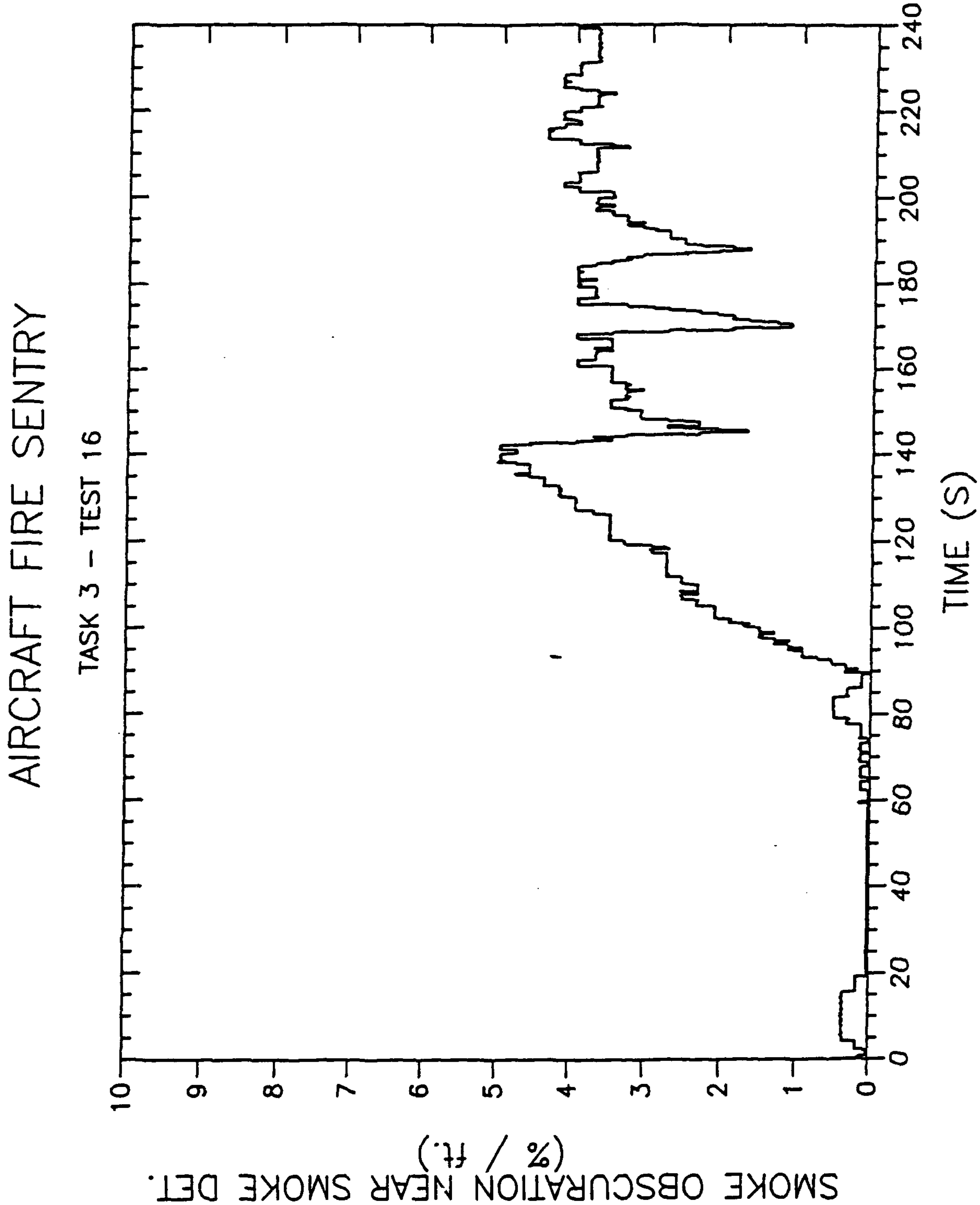
AIRCRAFT FIRE SENTRY

TASK 3 – TEST 15



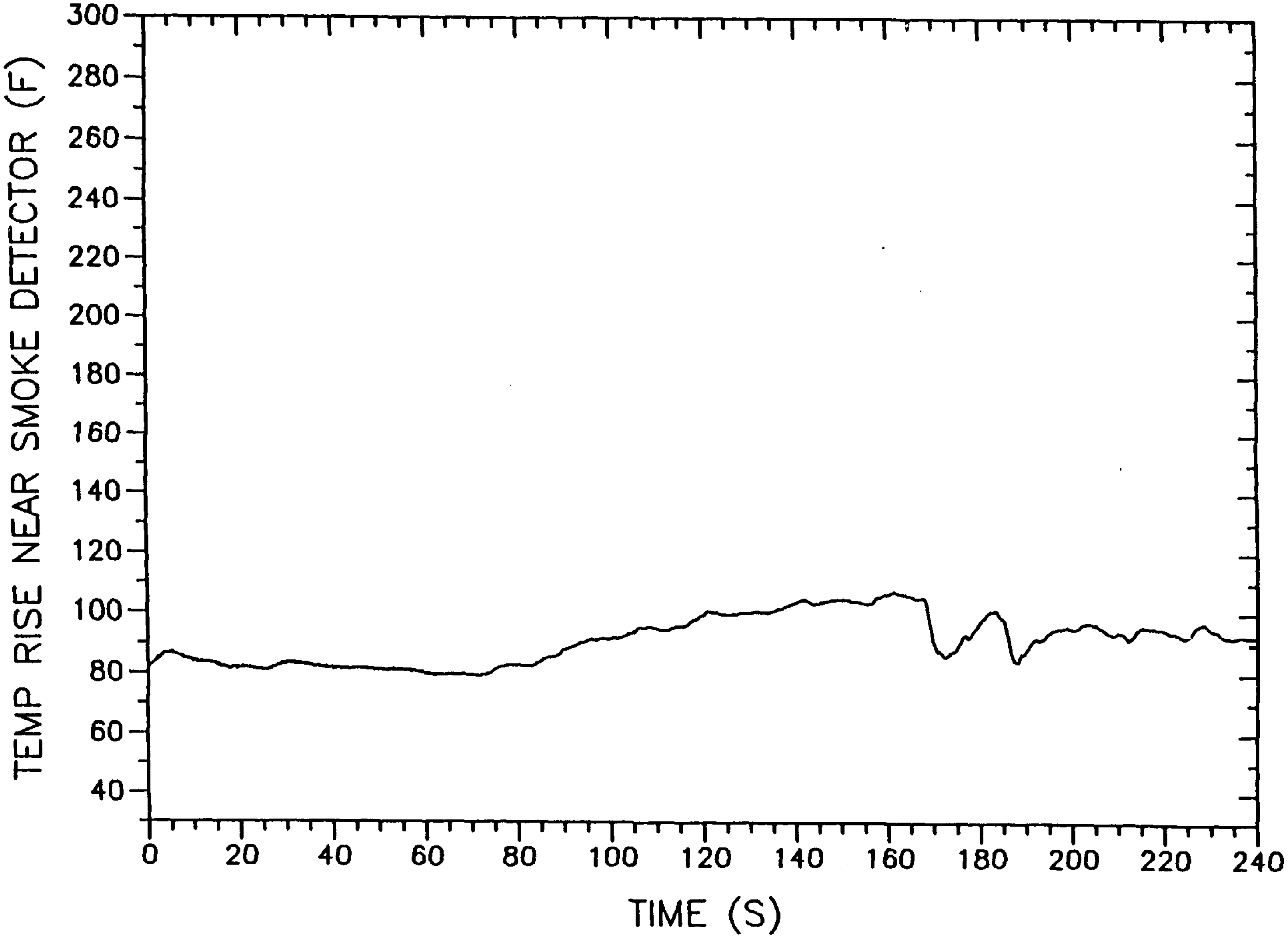


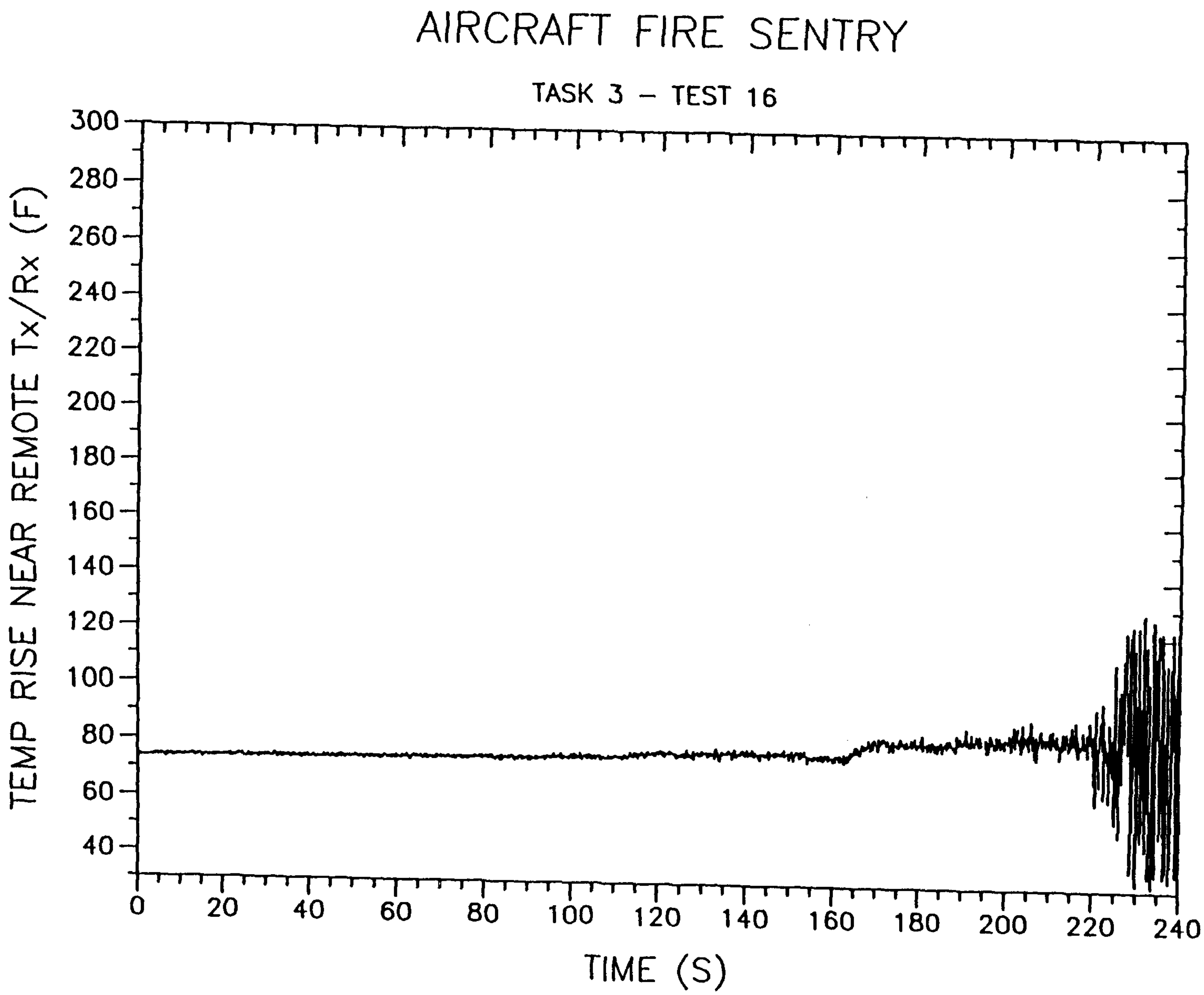
AIRCRAFT FIRE SENTRY
TASK 3 - TEST 16
TEST DURATION MARKER
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)

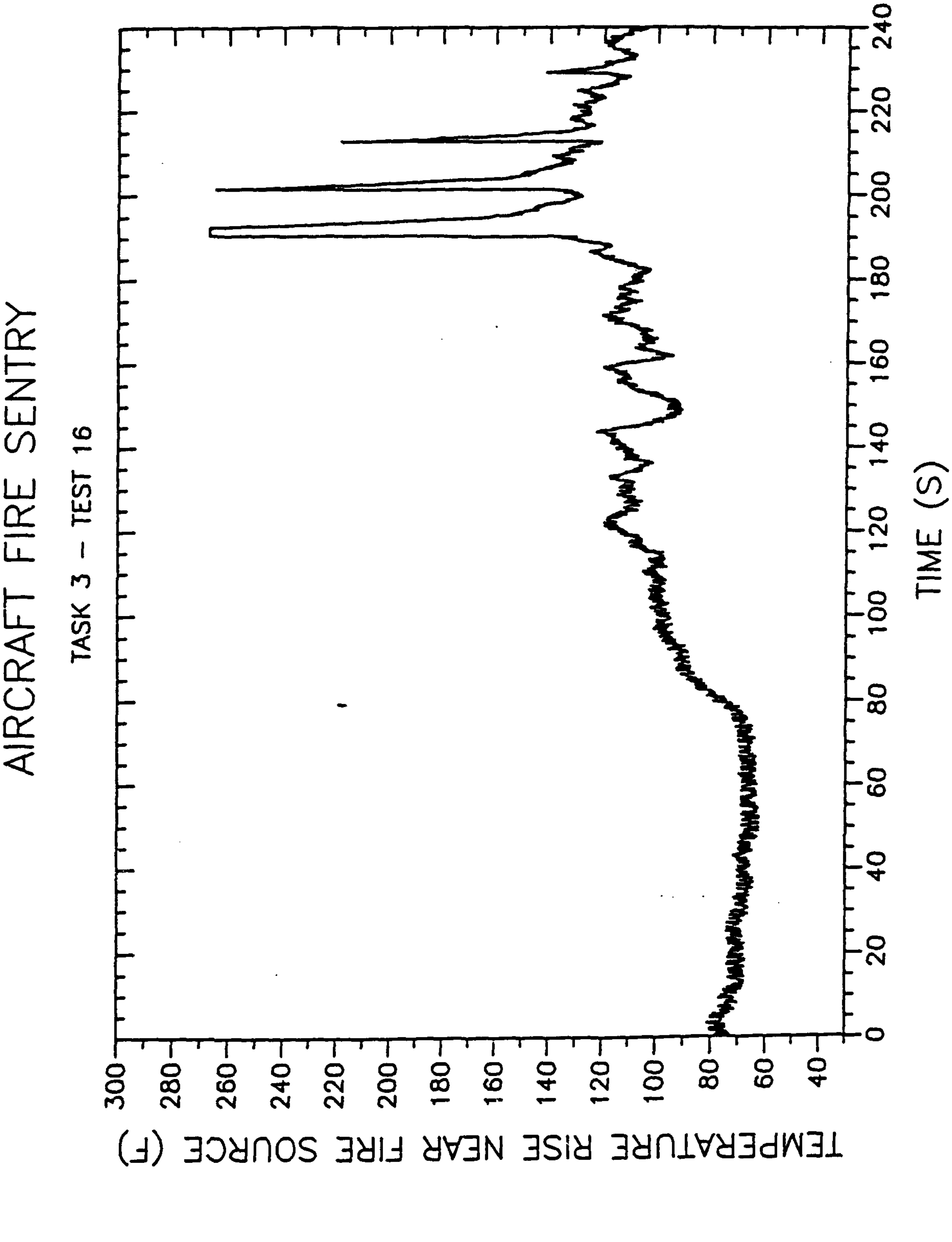

AIRCRAFT FIRE SENTRY
TASK 3 – TEST 16
SMOKE OBSCURATION NEAR SMOKE DET.
(% / ft.)
TIME (S)
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
120
140
160
180
200
220
240

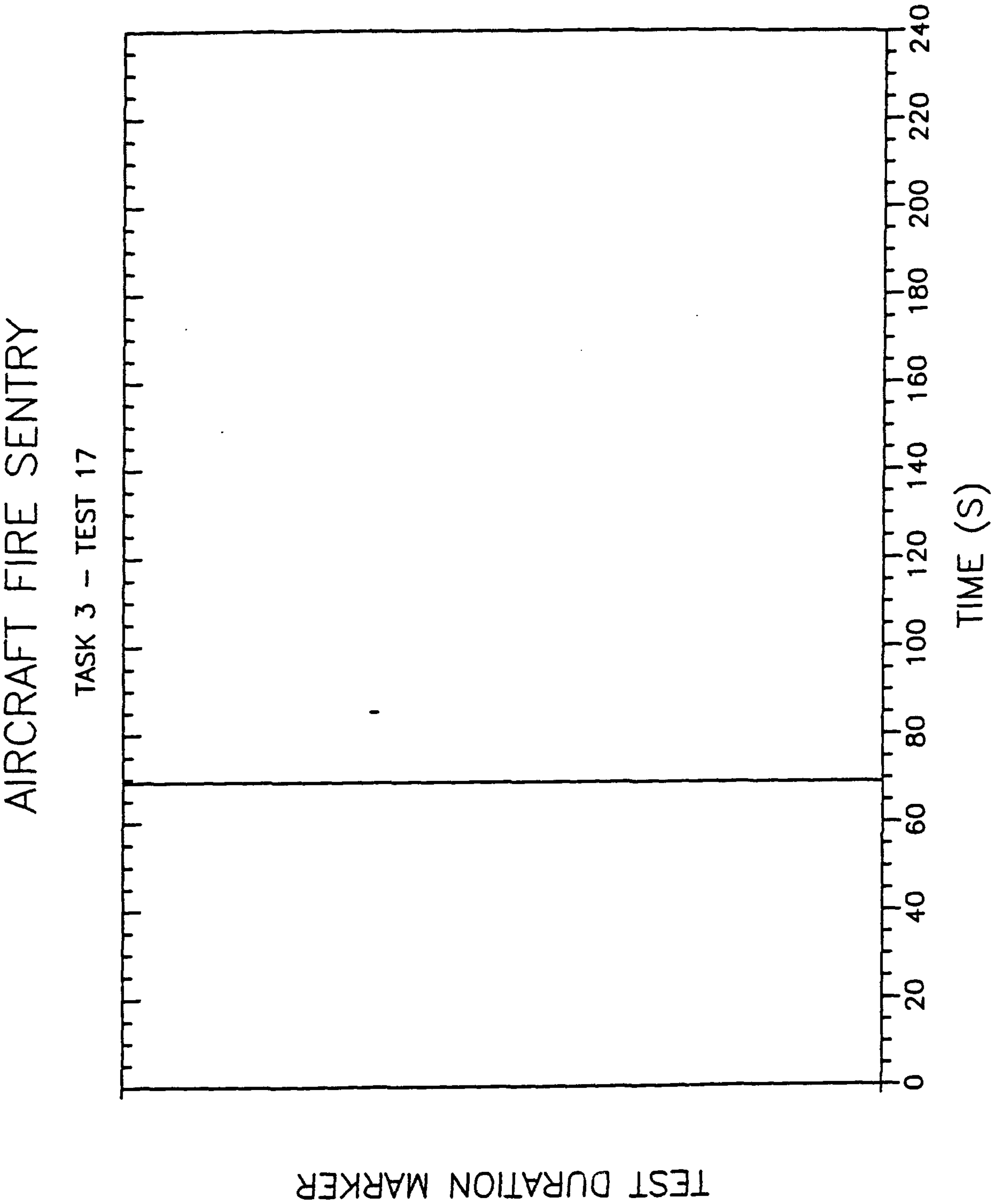
AIRCRAFT FIRE SENTRY

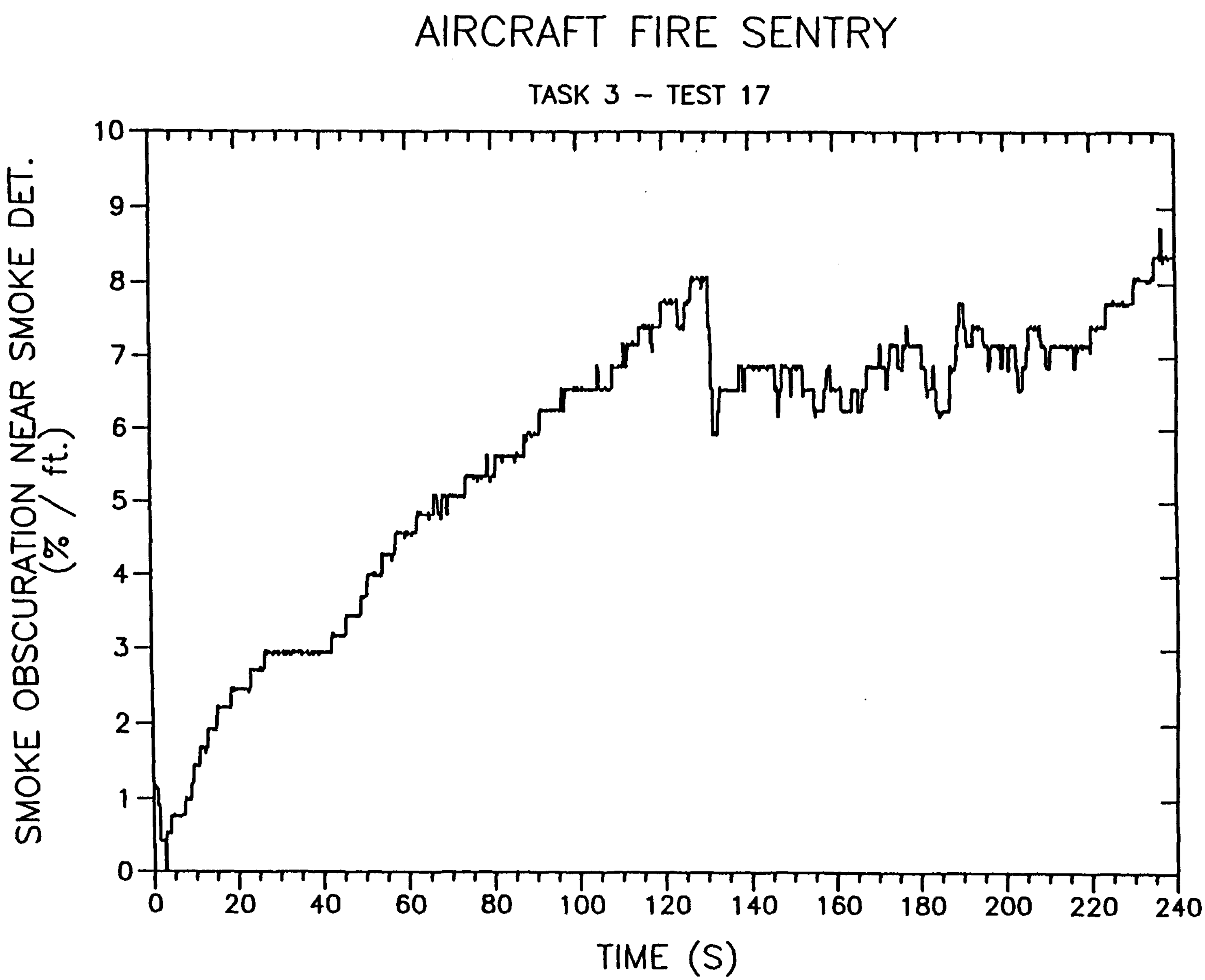
TASK 3 – TEST 16

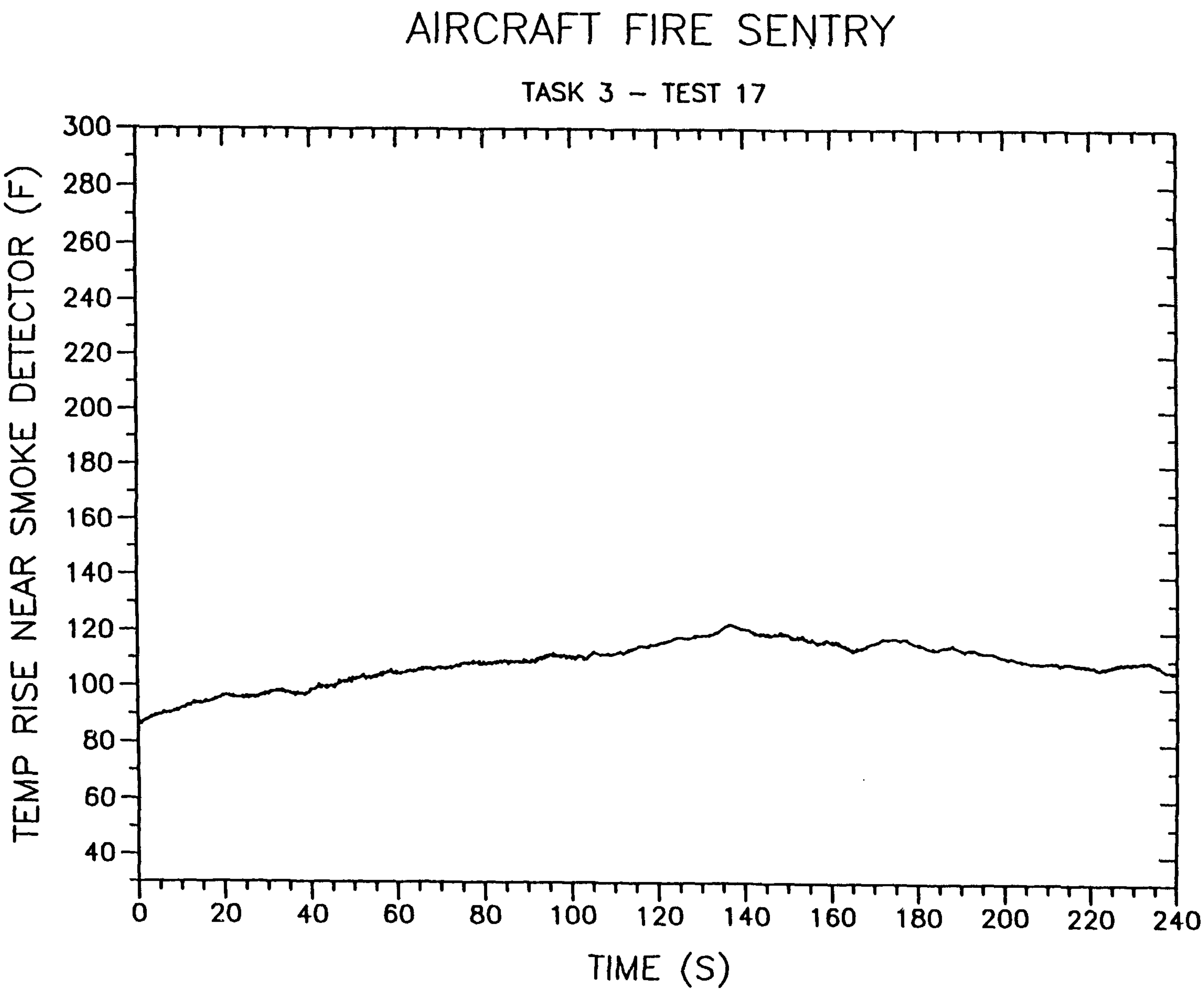



AIRCRAFT FIRE SENTRY
TASK 3 – TEST 16
TEMP RISE NEAR REMOTE Tx/Rx (F)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)


AIRCRAFT FIRE SENTRY
TASK 3 - TEST 16
TEMPERATURE RISE NEAR FIRE SOURCE (F)
TIME (S)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240

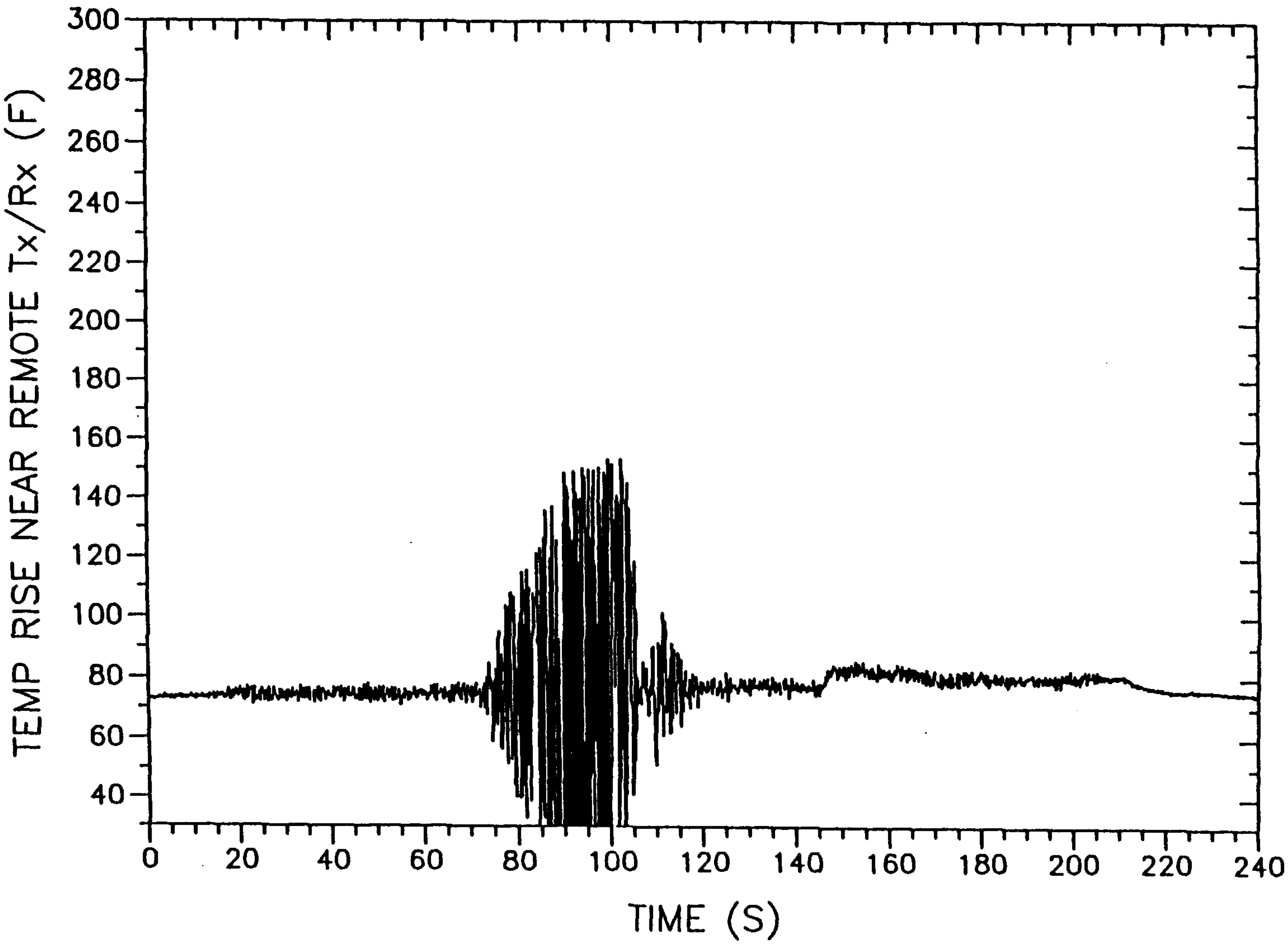

AIRCRAFT FIRE SENTRY
TASK 3 – TEST 17
TEST DURATION MARKER
TIME (S)
0
20
40
60
80
100
120
140
160
180
200
220
240

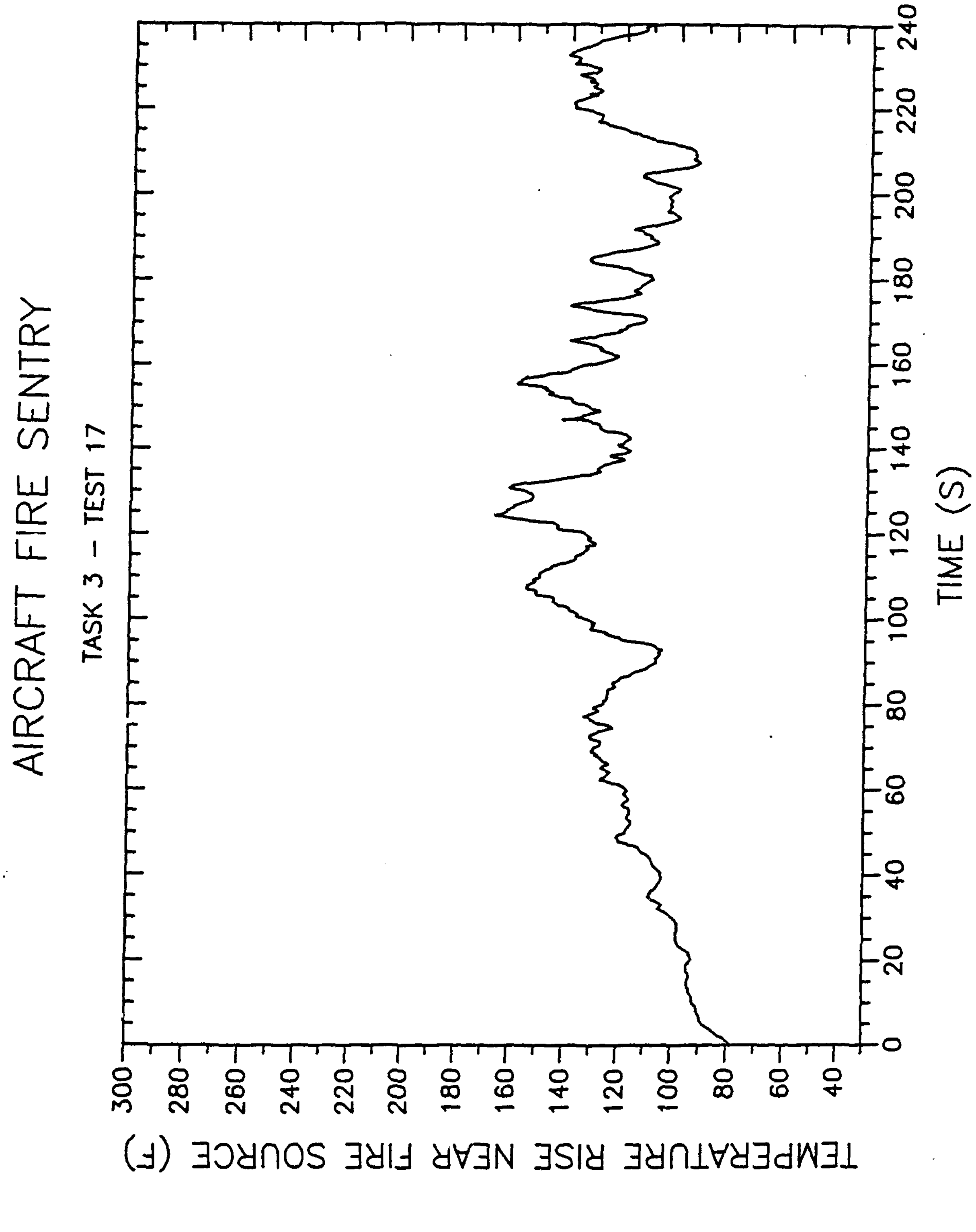

AIRCRAFT FIRE SENTRY
TASK 3 – TEST 17
SMOKE OBSCURATION NEAR SMOKE DET. (% / ft.)
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)


AIRCRAFT FIRE SENTRY
TASK 3 – TEST 17
TEMP RISE NEAR SMOKE DETECTOR (F)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180
200
220
240
TIME (S)

AIRCRAFT FIRE SENTRY

TASK 3 – TEST 17



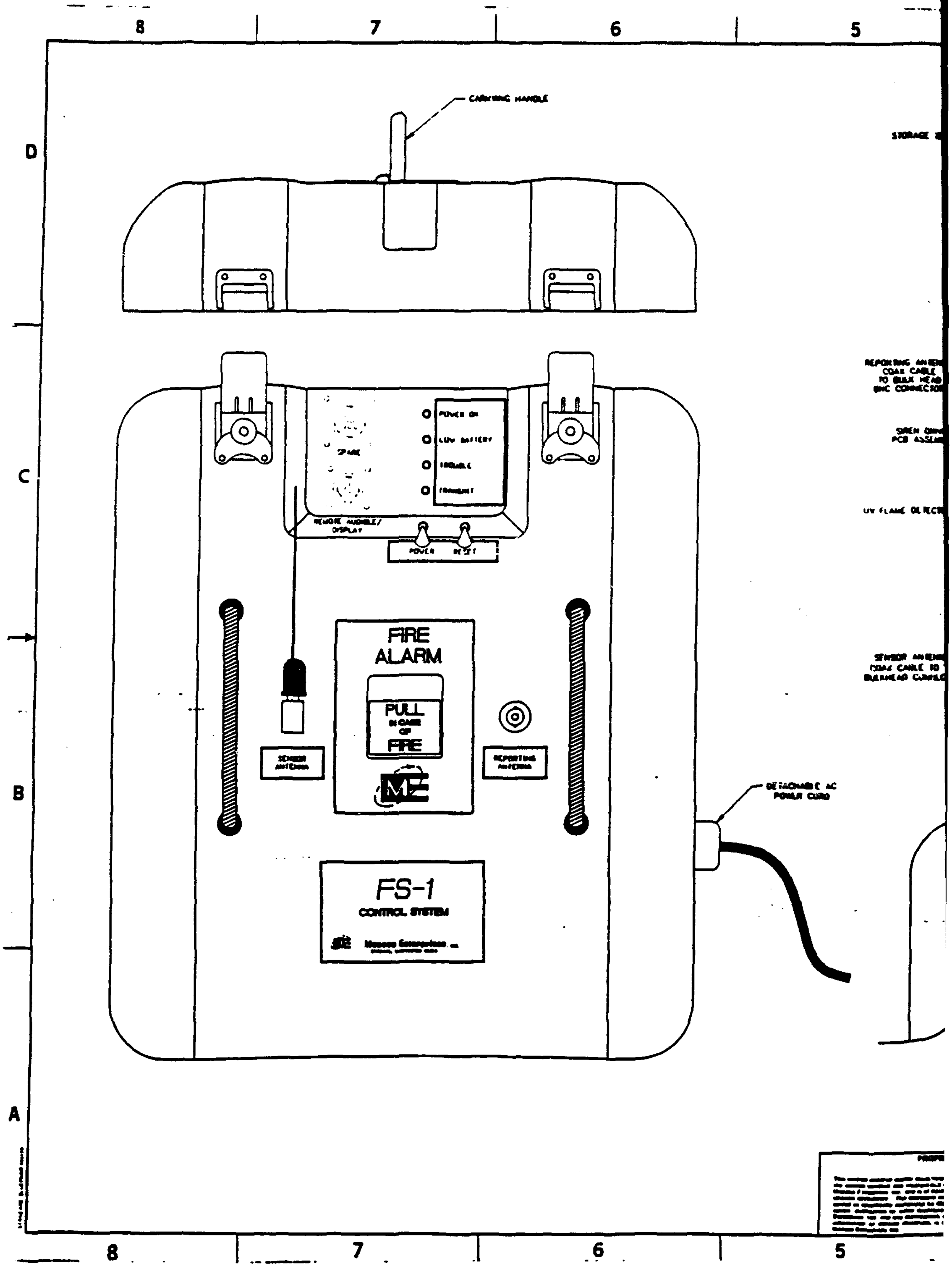


(The reverse of this page is blank.)

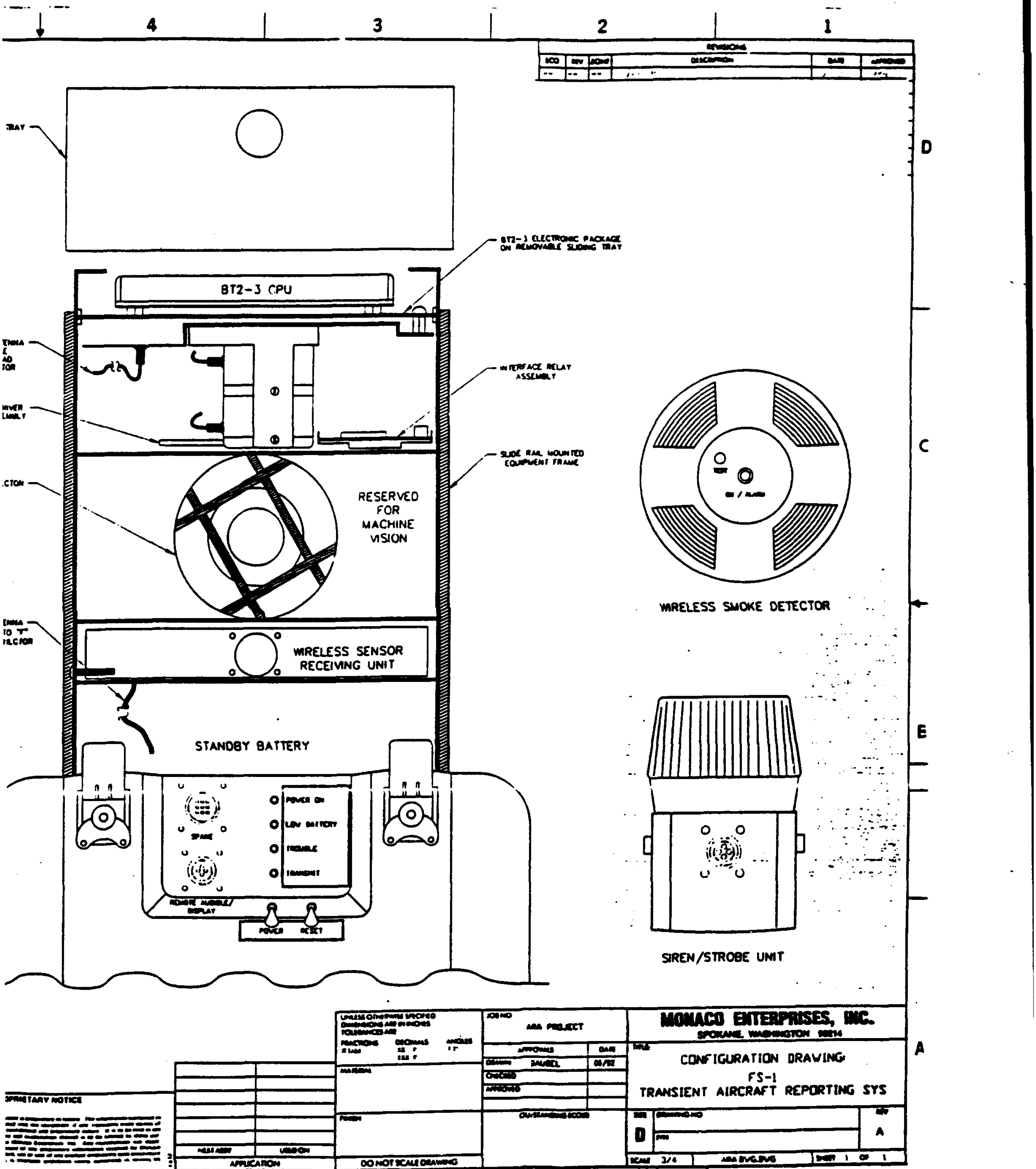
APPENDIX C

ANNEX C

HARDWARE INFORMATION AND DRAWINGS

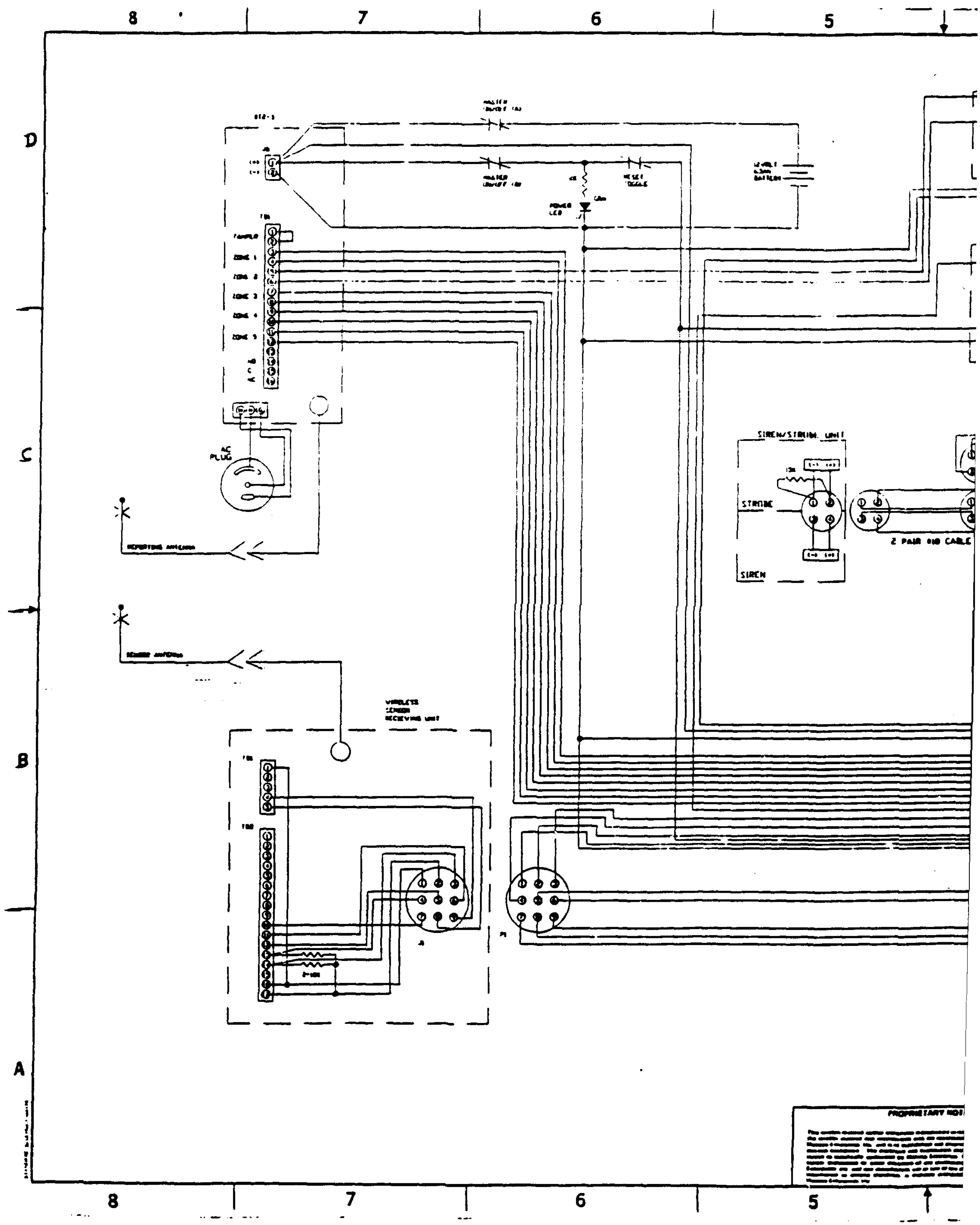


CARRYING HANDLE
POWER ON
LOW BATTERY
TROUBLE
TRANSMIT
SPARE
REMOTE AUDIBLE/ DISPLAY
POWER
RESET
FIRE ALARM
PULL IN CASE OF FIRE
SENSOR ANTENNA
REPORTING ANTENNA
FS-1
CONTROL SYSTEM
DETACHABLE AC POWER CORD
STORAGE

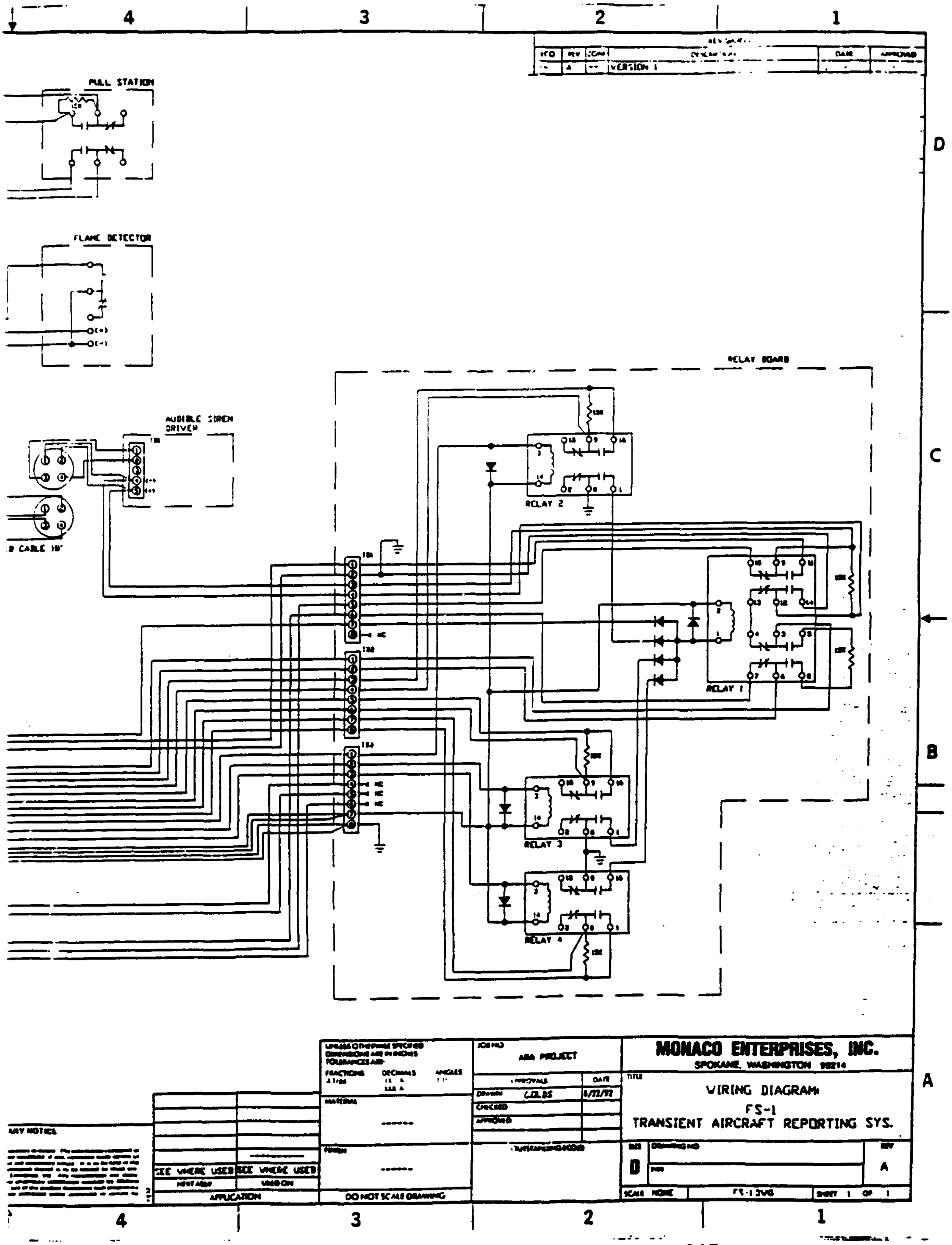


(The reverse of this page is blank.)

2



8
7
6
5
D
C
B
A
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
AC PLUG
POWER LED
RESET TOGGLE
SIREN/STROBE UNIT
STROBE
SIREN
2 PAIR #18 CABLE
WIRELESS SENSOR RECIEVING UNIT
PROPRIETARY NOTI



(The reverse of this page is blank.)

2

Monaco Enterprises INC.

E. 14820 SPRAGUE AVE., P.O. BOX 14129, SPOKANE, WASHINGTON 99214 (509) 926-6277

BUILDING TRANSCEIVER
BT2-3

Monaco's Building Transceivers (BT2) provide the communication link for Monaco's D-500 Radio Alarm System. Located in protected areas, the BT2 detects alarm (short) and trouble (open or single ground fault) conditions on zone inputs from local control panels or other supervisory devices. The BT2 transmits coded VHF-FM radio signals which identify the condition and zone address to the D-500. An alarm code is transmitted three times and a trouble code is transmitted twice. When the condition is removed from the zone input, the BT2 sends a restoration message.

The BT2 also monitors its own operating conditions. An ac power failure, low battery, or enclosure tamper is reported with the BT2 number.

Communication is supervised with interrogation by the central station equipment and reply by the BT2. The supervisory calls occur automatically at intervals of one to 24 hours as programmed by the user. All or individual BT2's can be interrogated manually at any time. The BT2 reply includes its current status.

The BT2-3 is compatible with all other D-500 System equipment. It provides five zone inputs. Its capabilities are outlined in the Features list. Monaco's BT2-4 provides 16 or 32 zone inputs. Refer to the catalog page which describes the BT2-4 and compare the Features to determine which model BT2 best meets your needs.

BT2-3 FEATURES

- Provides alarm and trouble monitoring for up to 5 zones
- Each zone may be selected for fire or security reporting
- Selectable 2 or 15 second condition verification delay before transmission per BT2
- Zones and transceiver are user addressable on DIP switches
- Enclosure tamper, low battery, and ac power failure are reported with BT2 address; ac fail transmission may be inhibited (Tamper switch optional)
- LED's identify BT2 status and zone alarm or trouble
- Remote test or auxiliary function relay included
- Test and reset switches and diagnostic tests programmed in the software aid maintenance operations
- 24-hour battery backup and charging circuitry (60-hour option available)
- Carrier detect identifies possible radio transmission interference; variable delay routine prevents simultaneous transmissions from several BT2's
- Microprocessor controlled
- 4 watts RF output power
- Selectable 115 or 230 Vac input

ORDERING INFORMATION

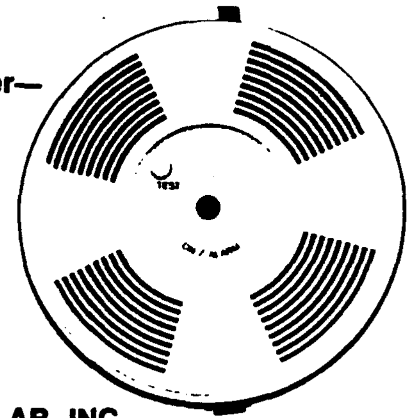
Part Number	Description
225-900-00	BT2-3 Building Transceiver

FM APPROVED

ESL NOW and into the Future	**INSTRUCTION MANUAL** part number 64812433, Rev. A bulletin 2704-IN, January 1989

ESL 370 SERIES BATTERY POWERED PHOTOELECTRONIC SMOKE ALARM

with Built-in Linear Supervised Wireless Transmitter— Battery Powered



Models 371, 373

ELECTRO SIGNAL LAB, INC.
75 Terry Drive, Hingham, MA 02043

TABLE OF CONTENTS

This Product is Listed by UNDERWRITERS LABORATORIES INC. and Bears the Mark: UL

1.0 GENERAL DESCRIPTION

The standard Model 371 and 373 are battery-powered photoelectronic smoke alarms with a built-in Linear Supervised wireless transmitter.

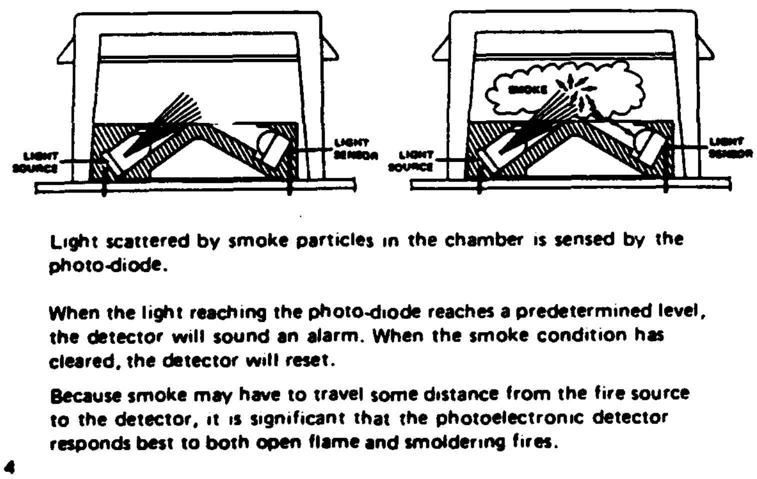
The Model 371 transmitter frequency is 303.875 Megahertz. The transmitter frequency for the Model 373 is 315 Megahertz.

When sufficient smoke is detected, or the test feature is operated, the detector will sound its alarm horn. The transmitter will produce a 3 second coded radio frequency (RF) transmission. This transmission is repeated at 30 second intervals as long as the alarm condition exists.

2.0 PRINCIPLE OF OPERATION

This Smoke Alarm brings quality, integrity, and dependability into your home. Properly installed, used and cared for, it will provide a high degree of protection for your family and property.

A high intensity infrared light emitting diode (LED) light source is pulsed in a sensing chamber that is designed for optimum smoke entry. The light source LED and a photo-diode sensor are positioned in the chamber at angles to each other so that when no smoke is in the chamber, the sensor sees virtually no light.



Light scattered by smoke particles in the chamber is sensed by the photo-diode.

When the light reaching the photo-diode reaches a predetermined level, the detector will sound an alarm. When the smoke condition has cleared, the detector will reset.

Because smoke may have to travel some distance from the fire source to the detector, it is significant that the photoelectronic detector responds best to both open flame and smoldering fires.

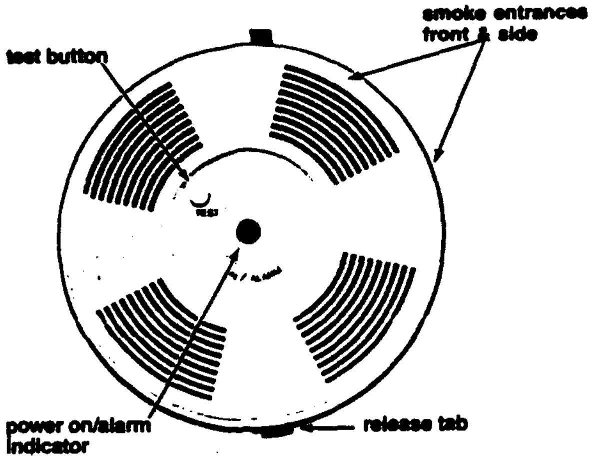


Figure 1

CAUTION

Early warning fire detection is best achieved by the installation of fire detection equipment in all rooms and areas of the household as follows:

A smoke alarm installed in each separate sleeping area (the vicinity of but outside of the bedrooms), and heat or smoke alarms in living rooms, dining rooms, kitchens, hallways, attics, furnace rooms, closets, utility and storage rooms, basements and attached garages.

5

3.0 SPECIFICATIONS

Power Source
Two Duracell MN1604 nine volt alkaline batteries (supplied)

Sensitivity
$3.1 \pm 0.5\%$/ft. obscuration

Operating Temperature Range
Tested 32° F to 120° F
(0° C to 50° C)
Not for use where normal ambient temperatures are outside the range of 40° F to 100° F.

Operating Humidity Range
0 to 95% RH

Horn Loudness
85 dB @ 10 ft.

Reset
Automatic

Test
Push-to-test button simulates gray smoke density of not greater than 6%/ft.

Power/Alarm Indicator LED
Standby – Flashing
Alarm – Steady

Radioactivity
Contains NO radioactivity

Color
OFF-White

6

Low Battery Signal
1 horn blip every fourteen seconds nominal for not less than seven days.

Size
6.1 in. diameter, 1.84 inches high
(15.5 cm diameter, 4.6 cm high)

Weight
With battery:
12 oz nominal (0.33 kg)
Without battery:
8 oz nominal (0.23 kg)

Transmitter Characteristics
Nominal center frequency:
Model 371 303.875 Mhz
Model 373 315 Mhz

Data Word Description:
Twenty-one Bits
Bit 1 Receiver Synchronization
Bits 2 thru 9 System Access Code
Bits 10 thru 17 Zone/Sensor ID (Channel/Code)
Bits 18 thru 21 Sensor Status e.g., alarm, low battery, etc.
A compatible receiver:
Linear Model SSR-32*
*Match to transmitter frequency

4.0 WHERE TO LOCATE

4.1 The smoke alarm should be installed in accordance with National Fire Protection Association (NFPA) Standard 74 which reads as follows:

2-1.1.1 Smoke detectors shall be installed outside of each separate sleeping area in the immediate vicinity of the bedrooms and on each additional story of the family living unit including basements and excluding crawl spaces and unfinished attics.[1]

2-1.1.2 For family living units with one or more split levels (i.e., adjacent levels with less than one full story separation between levels), a smoke detector required by 2-1.1.1 shall suffice for an adjacent lower level, including basements.

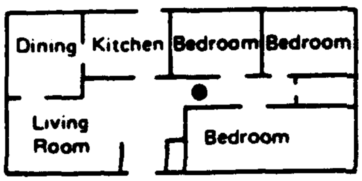
Exception: Where there is an intervening door between one level and the adjacent lower level, a smoke detector shall be installed on the lower level.

[1] The provisions of 2-1.1.1 represent the minimum number of detectors required by this standard. It is recommended that the householder consider the use of additional smoke or heat detectors for increased protection for those areas separated by a door from the areas protected by the required smoke detectors under 2-1.1.1 above. The recommended additional areas are: living room, dining room, bedroom(s), kitchen, attic (finished or unfinished), furnace room, utility room, basement, integral or attached garage, and hallways not covered under 2-1.1.1 above. However, the use of additional detectors remains the option of the householder.

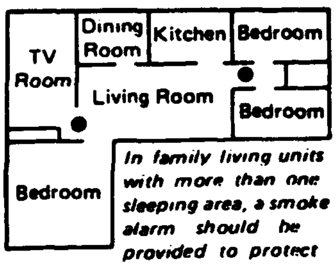
4.2 Ceiling mounted smoke alarms should be located in the center of the room or hall, or not less than 4 inches from any wall. When the detector is mounted on a wall, the top of the detector should be 4 to 12 inches from the ceiling.

4.3 Do not install smoke alarms where normal ambient temperatures are above 100°F (37.8°C), or below 40°F (4°C). Also, do not locate alarm in front of air conditioners, heating registers, or other locations where normal air circulation will keep smoke from entering the detector.

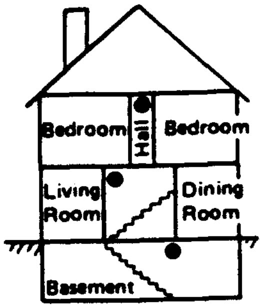
4.4 Additional information on Household Fire Warning is available at nominal cost from: The National Fire Protection Association, Batterymarch Park, Quincy, MA 02269. Request Standard No. NFPA 74. Contact your home Insurance Company for a possible reduction of your insurance premium.



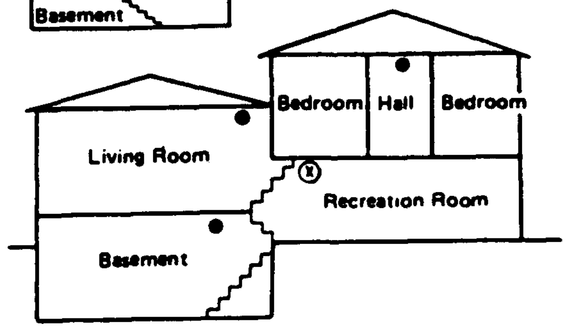
A smoke alarm should be located between the sleeping area and the rest of the family living unit.



In family living units with more than one sleeping area, a smoke alarm should be provided to protect each.



A smoke detector should be located on each story.



Split Level Arrangement

● *Indicates required smoke detector.*

Ⓧ *Indicates smoke detector is optional if door is not provided between Living and Recreation Rooms.*

5.0 PROGRAMMING, LOCATING, ACTIVATING AND INSTALLING

5.1 Programming

The ESL Model 371's or 373's radio frequency (RF) transmitter is programmed by setting the DIP switches located on the transmitter assembly inside the smoke detector. To open the detector cover, insert a small screwdriver (3/16" blade) or ballpoint pen into the slot shown in Figure 3 (pg. 12) and gently push forward. The latch will release.
You may open the cover.

With the cover open and away from you, locate the DIP switch assembly on the printed circuit board of the RF transmitter assembly (see Figure 2, pg. 11).

Set the switches according to the requirements of the receiving equipment being used. One 8 position DIP switch is provided for setting the system access code to match the receiver's setting (256 position settings). The second 8 position DIP switch sets the Zone/Sensor ID, which also has 256 possible settings. An example of a compatible receiver is the Linear Model SSR-32 of the same frequency as the detector.

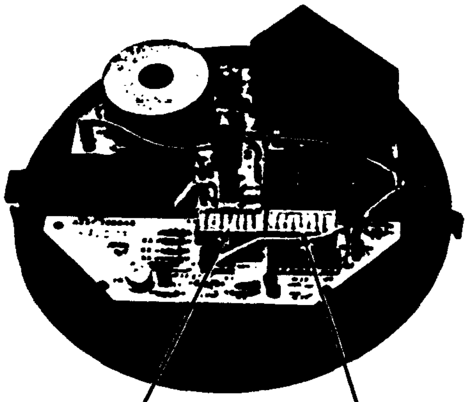


Figure 2

5.2 Activation

Energize the smoke alarm by installing the supplied battery in the rear compartment.

DO NOT force the batteries into the compartment. The smoke alarm is designed to prevent improper battery installation and the terminals are designated with a (+) and (−) to assist you in correct installation.

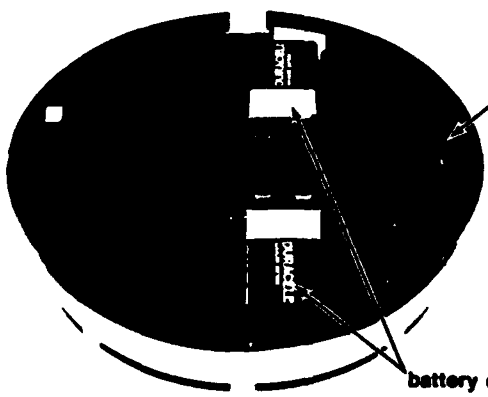


Figure 3

5.3 Locating

Before mounting the smoke detector, a "location test" must be performed to insure that the transmitter signal "reaches" the receiving equipment. To do this, complete the following:

1. Hold the smoke detector in its intended mounting location and in its intended orientation.
2. Press and hold the test button on the face of the detector until the alarm horn sounds (up to 20 seconds).
3. Verify receipt of an alarm signal at the receiver, and operation of any indicator (light, siren, dialer, etc.).

5.4 Installation

Remove the mounting bracket from the smoke alarm by depressing the release tab marked "PRESS" (see Figure 1, pg. 5). Pivot the bracket away from and free of the detector.

Use the bracket as a template to locate and mark the two mounting holes. Be careful to correctly orient the UP arrow on the bracket for correct positioning of the detector when wall mounting.

Drill two 3/16 inch diameter holes where marked, and insert the plastic expansion anchors. Hold the bracket in place and thread the two screws (supplied) into the anchors.

Install the detector on the bracket by hooking it at the top. Swing it gently toward the release tab until it "snaps" into the lock position.

TEST the smoke alarm immediately after completing the installation (see Section 8.0).

Caution should be observed during programming and installation to prevent dust, hair and other foreign matter from contaminating the optical sensing mechanism (see Section 7.0 on Maintenance).

6.0 CHECK-OUT AND TEST

See illustration on page 5 for the location of the LED indicator and the test button that are mentioned below.

After the battery is installed and the smoke alarm is mounted to its bracket, observe the LED indicator. In standby operation, it should flash approximately once every 7 seconds.

The smoke alarm is equipped with a unique test feature. Depress and hold the test button until the alarm sounds (up to 20 seconds), and the LED indicator emits a steady light. This will check the unit by simulating a maximum acceptable density of smoke for alarm.

THIS TEST SHOULD BE PERFORMED ONCE A WEEK.

If the smoke alarm does not sound after fully depressing and holding the test button for at least 20 seconds, see Section 9.0.

Verify proper operation of your receiving equipment on test of each smoke detector. Be certain to notify all necessary persons when testing your alarm system.

(See CAUTION note on next page.)

CAUTION: Testing by blowing smoke into the alarm does not provide an accurate means for measuring the sensitivity of the smoke alarm. Use of the test button provides a more accurate, full function test for proper operation.

Should you prefer to test your smoke alarm with smoke, be sure to clear the smoke from the smoke alarm after the electronic horn sounds to reset the device.

TESTING: ESL does not endorse the use of pressurized aerosols in detector testing.

Pressurized aerosols do not test detector sensitivity with accuracy. In fact, the result of such a test may be misleading. The test feature on ESL smoke detectors provides the most accurate test for minimum smoke sensitivity response.

The ESL product warranty does not cover contamination by aerosols.

7.0 MAINTENANCE

Very little maintenance is required for reliable operation of the smoke alarm. Simply vacuum the smoke entrances once a year depending on environmental conditions.

This smoke alarm has been factory tested and calibrated. Do not attempt to disassemble or alter the unit. Such action will void your warranty.

8.0 BATTERY REPLACEMENT

The Duracell MN 1604 alkaline battery* is the only acceptable battery for use in this smoke alarm. All warranties are void if the prescribed battery is not used. The battery is designed to power the smoke alarm for at least one year of normal use and testing. When the battery approaches the end of its useful life, the smoke alarm will automatically emit a beeping sound to signal the need for battery replacement.

To replace the battery:

- *Remove the smoke alarm from its mounting bracket by pressing the release tab (see Figure 1, page 5) and pivoting the alarm away from and off the bracket.*
- Remove both old batteries and discard.
- Wait at least one minute (a full 60 seconds) for the low battery condition to reset.
- Insert two fresh Duracell MN 1604 9-volt alkaline batteries.
- Install the smoke alarm onto the mounting bracket (see Section 5.4, page 14).
- *Test the smoke alarm as described in Section 6.0.*

*Duracell MN 1604 alkaline batteries are available at most supermarkets and convenience stores.

9.0 TROUBLESHOOTING

9.1 If the red light emitting diode (LED indicator) on the front of the smoke alarm does not flash approximately once every 7 seconds, OR the smoke alarm *does not* respond to the test button, OR the electronic horn *does not* sound, check to be sure the battery is properly connected and repeat the smoke alarm testing procedure.

If the unit fails to alarm after repeated testing, install a fresh battery and retest.

If the smoke alarm is still unresponsive, follow the return instructions in the warranty statement.

9.2 If your smoke alarm sounds, but the Radio Frequency transmission is *not acknowledged* by your receiving equipment, remove the smoke alarm from its mounting bracket (see Section 8.0) and perform the test again (see Section 6.0) in close proximity to the receiver. If retest is successful, relocation of the receiver and/or the smoke detector may be required. Reorientation of the smoke detector (i.e., ceiling-mounted vs. wall-mounted) may enable better reception of transmissions.

9.3 If the alarm sounds (without noticeable smoke):

a. Check carefully for signs of smoke or fire. If no fire exists, or no smoke is apparent, open the smoke alarm and remove the battery.

b. Vacuum around the smoke alarm to remove any excessive dust or cobwebs.

c. Reconnect the battery and perform the test as stated in Section 6.0.

d. If trouble persists, follow return instructions in the warranty statement.

9.4 This smoke alarm is equipped with an automatic trouble circuit that monitors the battery condition. If it emits a short beeping sound about every 14 seconds, the battery may need replacement. Check to see that the battery is properly connected. If the beeping continues, see battery replacement (Section 8.0).

9.5 If a trouble signal or alarm condition persists, follow the return instructions in the warranty statement.

10.0 FIRE PREVENTION AND ESCAPE

The purpose of an early warning smoke alarm is to detect the presence of fire in its early stages, and sound an alarm giving the occupants more time to exit the premise before the smoke reaches a dangerous concentration level.

Fires start even with the best of housekeeping and fire prevention procedures. Fire is an unexpected event. Early warning detection alerts occupants in time to act.

10.1 KNOW FIRE HAZARDS. No detection device can protect life in all situations. Therefore, safeguards should be taken to avoid such potentially dangerous situations as: smoking in bed, leaving children home alone, cleaning with flammable liquids such as gasoline.

The best fire protection is minimizing fire hazards through proper storage of materials and general good housekeeping techniques. A cluttered basement, attic, or other storage area is an open invitation to fire.

Careless use of combustible materials and electrical appliances, or overloading of electrical outlets are other prime causes in starting fires.

It is most important that explosive and/or fast burning materials be eliminated from the home, if at all possible.

Even after proper precautions have been taken, fires can start. Be prepared.

10.2 IN CASE OF FIRE. Leave immediately. Don't stop to pack or search for valuables. In heavy smoke, hold your breath and stay low — crawl if necessary. The clearest air is usually at the floor.

If you have to go through a closed door, carefully feel the door and door knob to see if undue heat is present. If they seem relatively cool, brace your foot against the bottom of the door with your hip against the door and one hand against the top edge. Open it slightly. If a rush of hot air is felt, slam the door quickly and latch it. Unvented fire tends to build up considerable pressure. Be sure all the household realizes and understands this danger.

Use your neighbor's phone or a street fire alarm box. The job of extinguishing the fire should be left to the professionals. Too many unforeseen things can occur when inexperienced people try to extinguish a fire.

10.3 BE PREPARED. Perform fire drills regularly. Use them to assure recognition of an alarm signal. For your protection, simulate different circumstances (smoke in hall, in living room, etc.). Then have everyone react to the situation.

Draw a floor plan and show two exits from each room. Frequently a knotted rope or ladder from a window will serve this purpose. It is important that children be instructed carefully, because they tend to hide in times of crisis.

It is imperative that one meeting place outside the home be established. You should insist that everyone meet there during an alarm. This will eliminate the tragedy of someone reentering the house for a missing member who is actually safe.

If you have children and/or invalids residing in your household, you can help your fire department. Most fire departments have window decals available for use in children's or invalid's bedrooms. Properly used these decals will quickly identify sleeping quarters of these individuals and show the fire department where to look first for members of your household.

11.0 LIMITED WARRANTY

Electro Signal Lab, Inc. (the "manufacturer") warrants this Smoke Alarm (battery excluded) to be free from defects in material and workmanship under conditions of normal use for a term of one year from the date of manufacture.

This warranty does not apply to units which have been subject to abuse, misuse, negligence or accident, or to which any modifications, alterations or repairs have been made or attempted.

This warranty is extended only to the original purchaser of the smoke detector and may be enforced only by such person. During the warranty period, if the detector or any warranted components thereof becomes defective, it will be replaced or repaired without charge if returned in accordance with the following instructions:

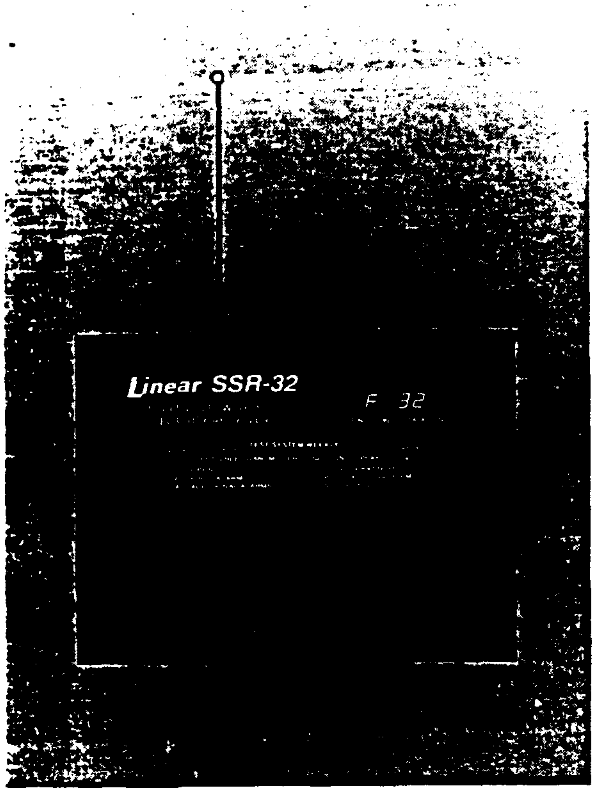
The detector should be packed carefully in a well padded and insulated carton and returned, postal charges prepaid to: ELECTRO SIGNAL LAB, INC., 75 Terry Drive, Hingham, MA 02043. A note should be included advising the nature of the malfunction. Care must be exercised in the proper packing of detectors returned under this warranty as Manufacturer will not be responsible for warranty repairs to equipment damaged because of improper packing.

"THE ABOVE WARRANTY IS IN LIEU OF ALL OTHER EXPRESS WARRANTIES, AND IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE LIMITED IN DURATION TO A PERIOD OF ONE YEAR FROM THE DATE OF MANUFACTURE. UNDER NO CIRCUMSTANCES SHALL

MANUFACTURER BE LIABLE TO THE PURCHASER OR ANY OTHER PERSON FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY NATURE, INCLUDING WITHOUT LIMITATION DAMAGES FOR PERSONAL INJURY OR DAMAGES TO PROPERTY, AND HOWEVER OCCASIONED, WHETHER ALLEGED AS RESULTING FROM BREACH OF WARRANTY BY MANUFACTURER, THE NEGLIGENCE OF MANUFACTURER OR OTHERWISE. MANUFACTURER'S LIABILITY WILL IN NO EVENT EXCEED THE PURCHASE PRICE OF THE PRODUCT. SOME STATES DO NOT ALLOW LIMITATIONS ON HOW LONG AN IMPLIED WARRANTY LASTS, OR THE EXCLUSION OR LIMITATION OF INCIDENTAL OR CONSEQUENTIAL DAMAGES, SO THE ABOVE LIMITATIONS AND EXCLUSIONS MAY NOT APPLY TO YOU. UNLESS A LONGER PERIOD IS REQUIRED BY APPLICABLE LAW, ANY ACTION AGAINST MANUFACTURER IN CONNECTION WITH THIS SMOKE DETECTOR MUST BE COMMENCED WITHIN ONE YEAR AFTER THE CAUSE OF ACTION HAS ACCRUED.

No agent, employee or representative of the Manufacturer nor any other person is authorized to modify this warranty in any respect. Repair or replacement as stated above is the exclusive remedy of the purchaser hereunder.

This warranty gives you specific legal rights and you also have other rights which vary from state to state."



MODEL SSR-32

SUPERVISED WIRELESS SECURITY RECEIVER

Installation and Operation Manual

Linear
2055 Corte Del Nogal
Carlsbad, CA 92009
(619) 438-7000 • (800) 421-1587
CA (800) 321-1845 • FAX (619) 438-7043
Customer/Technical Service: (800) 392-0123

TO THE INSTALLER...

The Linear Model SSR-32 is a Supervised Wireless Receiver/Annunciator. Correctly installed and properly used, it will provide years of reliable service.

The instructions in this manual are intended for the guidance of security installers. It is recommended that, in order to become fully familiar with this system, installers read the entire manual before beginning any work.

If you require additional information, please call Linear Technical Services Department at 1-800-392-0123, or from inside California 1-800-321-1845.

CONTENTS

1. INTRODUCTION

A Linear Supervised Wireless Security System is a self-monitoring, multi-purpose system comprised of wireless components designed for use in residential and commercial installations.

The SSR-32 is a 32-channel input, eight-zone output, supervised receiver/annunciator that acts as a wireless zone expander for conventional hardwire control panels.

Transmitters send coded radio signals to the SSR-32 which receives, processes, displays, and transfers each radio signal report to a hardwire control panel.

A typical supervised wireless system includes the following components:

- Model SSR-32 receiver/annunciator
- Model ST stationary door/window transmitter(s)
- Model ST-1 portable panic-button transmitter(s)
- Model 50S40 supervised passive infrared detector(s)
- Model ESL 371 supervised smoke detector(s)
- A hardwire control panel and its accessories

➡ *NOTE: Only the Linear "S" Series supervised transmitters can be used with the SSR-32. Linear's "D" Series standard digital transmitters are **not** compatible with this receiver.*

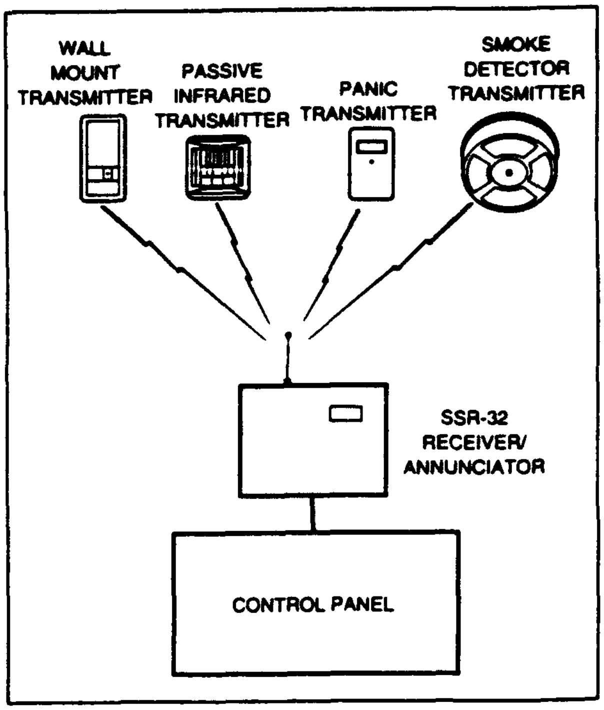


Figure 1. Typical Supervised System Configuration

2. SUPERVISED SYSTEM OPERATION

TRANSMITTER REPORTS AND SIGNALS

The SSR-32 monitors five types of transmissions from Linear "S" series transmitters:

Alarm Reports

Transmitters instantly signal an **alarm** report when the contact wired to the transmitter is faulted.

Restore Reports

Transmitters instantly signal a **restore** report when the contact wired to the transmitter is returned to its normal state.

Low Battery Reports

Transmitters test their internal 9-volt battery under load every 60 seconds. If the battery tests at 7.5 volts or less, a **low battery** report is instantly sent to the receiver. The test is disabled until the low battery is replaced.

Test Signal

When the test button is pressed on any stationary transmitter, a unique **test** signal is sent to the receiver. This signal is used when programming the SSR-32, and for routine testing of the system.

Status Reports

When the status option is selected in the transmitter, a **status** report is sent every hour. This report, which contains all of the previous information, updates the SSR-32's memory so that it knows each transmitter is still active and operating in the correct mode.

RECEIVER LED DISPLAYS

The transmitter's reports (or the exception thereof) are shown on the SSR-32 LED display in a continuous cycle. The left display shows the *condition*, and the right displays indicate the transmitter *location*, by channel number.

There are six possible *condition* displays:

"O" for OPEN

"O" shows that the transmitter displayed has sent an **alarm** report. As long as the transmitter is faulted, the "O" will remain on the display and the ZONE output programmed for that transmitter will remain faulted. A **restore** report from the same transmitter will clear the "O" indication.

"L" for LOW BATTERY

The "L" indication shows that the transmitter displayed has sent in a **low battery** report. The "L" will remain on the display until the battery is replaced in the transmitter, and a **test**, **status**, **alarm**, or **restore** report is sent from that transmitter. Whenever an "L" is indicated on the display, the LOW BATTERY output will activate.

☆ "P" for STATUS PROBLEM

"P" indicates that the SSR-32 has not received a **status** transmission from the transmitter displayed during a period of 8 hours. The "P" will remain on the display until a manually actuated **test** signal is received from that transmitter. Whenever a "P" is indicated on the display, the STATUS output will activate.

☆ "F" for FIRST-ALARM

The "F" indication is used for alarm memory of the first **alarm** report that occurred. The transmitter displayed has been, or currently is, faulted with the control panel armed. The first "O" indication that appears when the control panel is armed will cause an "F" to be displayed for alarm memory of that channel as the first alarm in. Additional "O" indications will cause "A's" to be displayed (see below). If the transmitter channel is programmed for an Exit/Entry Delay zone, the "F" will occur *after* any delays have expired if the transmitter is still faulted. The "F" alarm memory will remain on the display even after the control panel is disarmed. The "F" will be erased the next time the control panel is armed.

☆ "A" for ADDITIONAL ALARMS

The "A" indication is used for memory of any *additional* alarms. The transmitter channel displayed has been, or currently is, faulted with the control panel armed. Any secondary "O" indication that appears when the control is armed will cause an "A" to be displayed for alarm memory of that channel. If the transmitter channel is programmed for an Exit/Entry Delay zone, the "A" will occur *after* any delays have expired if the transmitter is still faulted. The "A" alarm memory will remain on the display even after the control panel is disarmed. Any "A's" will be erased the next time the control panel is armed.

☆ "S" for SHUNTED

"S" indicates that the transmitter channel indicated has been shunted out of the system by the SSR-32 Auto Shunt or Manual Shunt function. **Alarm** and **restore** reports from this transmitter will be ignored and the zone output for that channel will not be triggered as long as it remains shunted. **Status**, **test**, and **low battery** reports are not affected. Whenever "S" is indicated on the display, the SHUNTED output will activate.

Figure 2 illustrates a first-alarm condition on Channel 32, indicating that the transmitter assigned to Channel 32 was the first one tripped while the system was armed.

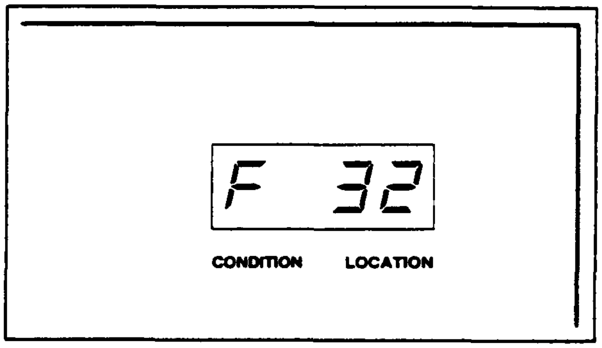


Figure 2. Display Showing First Alarm on Channel 32

3. NEW RECEIVER FEATURES

AUTO SYSTEM CODING

Setting the receiver system code has been simplified. Instead of having to set a code on switches in the SSR-32, the receiver automatically assumes the system code of the ***first*** transmitter programmed into the receiver's memory.

HIGH CURRENT OUTPUTS

The SSR-32 outputs are now buffered with individual transistors for each of the zone and supervisory signal lines. Each output can switch up to 100 mA to common, enabling direct connection to most control panels or external relays.

POWER SUPERVISION RELAY

An on-board power monitoring relay provides closed, dry relay contacts across the POWER RELAY terminals as long as the receiver has DC power. If DC power is removed, the contacts will open. The power monitoring relay can be disabled to increase backup battery standby time.

SELECTABLE ARMED INPUTS

A jumper block selects between four types of ARMED INPUT signals that can be produced by the control panel connected to the receiver. The SSR-32 can accept voltage-when-armed (high), ground-when-armed (low), in a continuous or pulsing (blinking ARMED LED) signal.

TERMINAL BLOCKS

To facilitate easy connection to the SSR-32, two sets of terminal blocks (TB1 & TB2) have been provided.

TEST DISPLAY

When a **test** signal is sent from any system transmitter the rightmost decimal point on the location display will light, indicating that the **test** signal was properly received. Whenever the test display is lit, the TEST output will activate.

4. STANDARD RECEIVER FEATURES

AUTO RESTORE

For security, transmitter **alarm** reports always last longer than **restore** reports. If an installation has more than one passive infrared detector, or a situation exists where two or more transmitters are triggered adjacently, an **alarm** transmission may override a **restore** transmission. This causes an "O" to persist on the SSR-32 display with its corresponding ZONE output remaining faulted, even when the transmitter is actually restored.

The SSR-32 provides an Auto Restore option that converts Zones 3,4,5 and 6 to self-restoring zones. This type of zone does not require a **restore** transmission to clear the display and return the ZONE output to a normal state. The **alarm** and **test** signal responses, along with the **status** and **low battery** supervisory functions of these zones, when converted, are not effected.

EXIT DELAY

The SSR-32 furnishes an adjustable Exit Delay on transmitter channels programmed for Zones 1, 2, and 3. This gives the user the ability to exit the premises during the delay time without causing the receiver's alarm memory display to latch. **The zone outputs are not delayed, only the latching of the alarm memory display is delayed.**

The Exit Delay timer starts when the system is armed, and continues until its selected time (10, 20, 30, or 40 seconds) expires.

AUTO-SHUNT

The Auto-Shunt feature works in conjunction with the Exit Delay to automatically bypass any faulted transmitters after the system is armed.

When the Exit Delay time expires, any transmitter(s) that are recognized by the receiver as being in the faulted (**alarm**) state (whether actual or created because of a blocked **restore** transmission) are automatically shunted. The display will show an "S" along with the shunted transmitter's channel number(s). A shunted transmitter can not cause its programmed ZONE output to activate upon alarm.

Any transmitter channel will remain shunted until the receiver recognizes a **restore** signal from that transmitter or the system is disarmed. The shunt is then automatically removed. Any subsequent **alarm** transmissions from the transmitter channel will again be able to activate its programmed ZONE output.

ENTRY DELAY

The SSR-32 furnishes an adjustable Entry Delay on transmitter channels programmed for Zones 1, 2, and 3. This gives the user the ability to enter the premises without causing the receiver's alarm memory display to latch as long as the system is disarmed before the delay time expires. **The zone outputs are not delayed, only the latching of the alarm memory display is delayed.**

The Entry Delay timer starts when the SSR-32 receives an **alarm** transmission on transmitter channels programmed for Zones 1, 2, or 3. The timer continues until its selected time (20, 30, 40, or 50 seconds) expires. If the system is not disarmed when the time expires, the alarm memory display latches to indicate the transmitter channel(s) that caused the alarm. Any subsequent alarms will also be indicated on the display. The alarm memory display remains latched until the next time the system is rearmed.

FIRST-ALARM INDICATION

The First-Alarm indication gives the user or installer the ability to pinpoint the location of the initial intrusion.

When the system is armed, the first transmitter to send an **alarm** transmission (if it is programmed for an Exit/Entry Delay zone, the delay period must be expired) causes the alarm memory display to show an "F" with the corresponding channel number. Any following **alarm** transmissions from other transmitters causes the alarm memory display to show an "A" with the corresponding channel number.

UNARMED ALERT

The Unarmed Alert option is used to annunciate signals from transmitters used for 24-hour functions (fire, panic, medical, etc.).

This option causes the alarm memory to latch on transmitter channels programmed for Zones 6,7, and 8 even if the system is disarmed. The alarm memory display remains latched until the next time the system is re-armed.

DISPLAY BLANKING WHILE ARMED

Display blanking saves current and extends the time that the system operates off a backup battery during AC power loss.

When the Display Blanking option is selected, the SSR-32 display goes blank when the system is armed. During blanking, any display information is stored in memory. When the system is disarmed the display is re-enabled, revealing all stored information.

The blank display also provides positive visual indication that the system is armed.

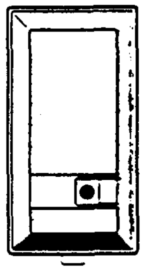
STATUS MEMORY

The Status Memory feature gives the installer the ability to pinpoint any transmitter experiencing intermittent or marginal radio reception.

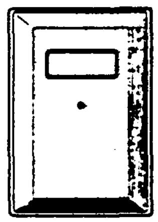
This feature latches any status problem "P" display until a manually actuated **test** transmission is received from the problem transmitter's channel.

5. SUPERVISED DIGITAL TRANSMITTERS

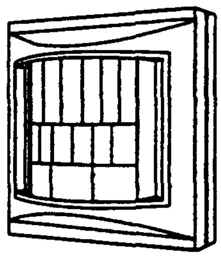
The following "S" Series transmitters are available:



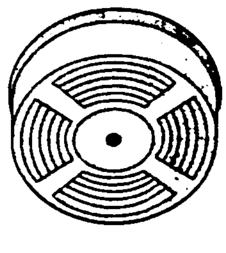
ST Wall-Mounted Door/window Transmitter



ST-1 Portable Panic Button



50S40 Supervised Passive Infrared Detector



ESL 371 Supervised Smoke Detector

Permanently stationed transmitters, such as the wall-mounted ST or PIR, are fully supervised and should be installed at every location where protection is desired. These stationary transmitters provide routine **status** reports every hour and should be coded to fully supervised zones.

PORTABLE ST-1 TRANSMITTERS

Portable transmitters, such as the ST-1, are semi-supervised. Because they may be taken out of range of the receiver, they do not signal hourly **status** reports. They do, however, provide a **low battery** report if the condition should occur. These transmitters do not send **restore** reports and therefore must be coded to Zones 7 or 8.

➡ *NOTE: If fully supervised portable transmitters are required, two jumpers must be cut inside the ST-1 to cause the transmitter to send* ***status*** *and* ***restore*** *reports. The unit can then be coded to Zones 1-6 (see Figure 3).*

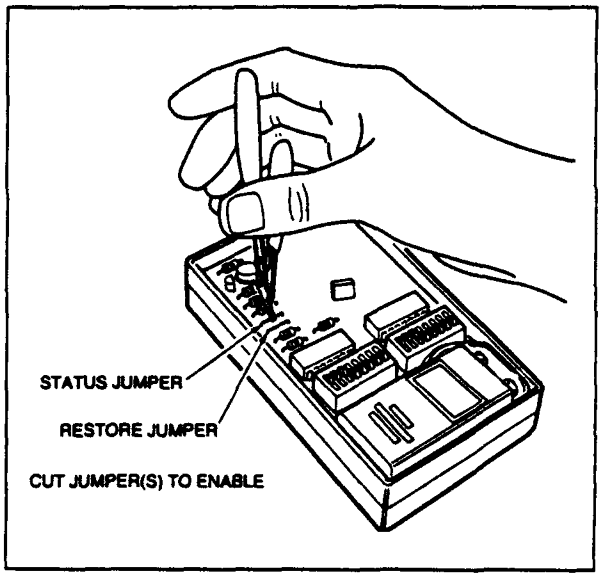


Figure 3. Cutting the ST-1 Status and Restore Jumpers

6. TRANSMITTER CODING

Linear "S" Series supervised transmitters communicate with the SSR-32 via a broadcasted digital code. These transmitters incorporate two groups of switches labeled CHANNEL and SYSTEM for setting the system, channel, and zone codes. In the stationary ST transmitter a third, MODE switch, is also used. The code switches are accessible through the back of each transmitter case; with the ST and ST-1 models, the case may be opened by unsnapping and lifting off the back cover (see Figures 4 and 5).

SETTING THE TRANSMITTER SYSTEM CODE

One of the 256 discrete eight-digit codes must be chosen for the system code. **Keys 1-8 on the SYSTEM switch in each "S" Series transmitter used should be set to the same code.** Factory set codes should not be used. In addition, the following codes should not be used: (1) all keys set to ON; (2) all keys set to OFF; (3) keys set in alternating OFF-ON or ON-OFF positions. **Do not** use a pencil or pen to code transmitters. Graphite from pencil lead and ink can contaminate the switch and cause a failure.

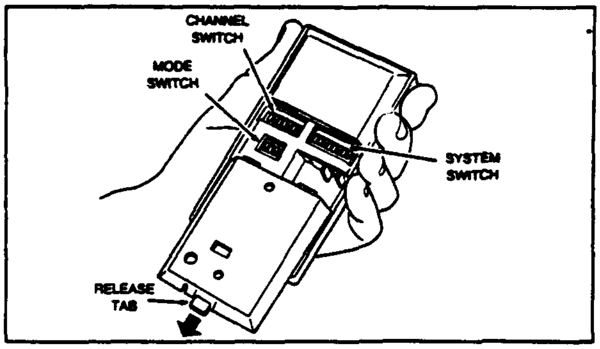


Figure 4. Wall-mounted ST Transmitter

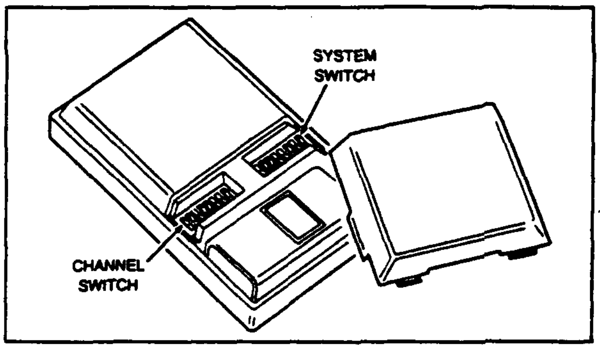


Figure 5. Portable ST-1 Transmitter

SETTING THE TRANSMITTER CHANNEL AND ZONE CODE

By use of binary codes, the eight-position CHANNEL coding switch establishes the input *channel* and the output *zone* to which the transmitter is assigned. Figure 6 shows a transmitter CHANNEL switch set to Zone 6, Channel 20.

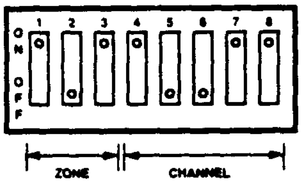


Figure 6. Example Channel Coding Switch

ZONE OUTPUT IDENTIFICATION

CHANNEL switch keys 1-3 identify the ZONE output that the transmitter will activate.

Different options can be selected for some of the zones. These alternatives are described in Sections 3,4, 9 and 10 and are selected with the OPTION switch. They are:

- ✓ Zones 1, 2, and 3 are always EXIT/ENTRY DELAY zones. Different delay times are selected with the OPTION switch.
- ✓ Zones 6, 7, and 8 can be selected as UNARMED ALERT zones for transmitters used in 24-hour applications.
- ✓ Zones 7 and 8 are always AUTO-RESTORE zones, although Zones 3, 4, 5, and 6 can also be selected as AUTO-RESTORE zones for non-restoring ST-1 transmitters or multiple PIR installations.
- ✓ Zones 7 and 8 are always semi-supervised and do *not require* **status** reports. These zones are used for portable transmitters that may be taken out of range of the receiver.

Following the coding scheme in Figure 7, set the keys 1-3 on the CHANNEL switch in the transmitter to assign it to the specific zone that fits its application.

ZONE	EX&ENT DELAY (STD)	AUTO RESTORE (STD)	AUTO RESTORE (OPT)	UN-ARM ALERT (OPT)	CHANNEL SWT #		
					1	2	3
1	✓				OFF	OFF	OFF
2	✓				OFF	OFF	ON
3	✓		✓		OFF	ON	OFF
4			✓		OFF	ON	ON
5			✓		ON	OFF	OFF
6			✓	✓	ON	OFF	ON
7		✓		✓	ON	ON	OFF
8		✓		✓	ON	ON	ON

Figure 7. Zone Options and Transmitter Zone Coding

INPUT CHANNEL IDENTIFICATION

CHANNEL switch keys 4-8 in the transmitter identify its input channel. Following the coding scheme shown in Figure 8, set the keys to assign that transmitter to a specific channel.

➡ *NOTE: Do not code any transmitter for Channel 32, Zone 8. Channe. 32 can be used, however, with any other zone (-7).*

✱ **CAUTION! The channel code must be unique for each transmitter. Do not set more than one transmitter to each channel code. A maximum of 32 transmitters can be used with each SSR-32 system.**

SETTING THE ST TRANSMITTER MODE SWITCH

The four-key MODE switch in the ST transmitter controls the way the unit functions. No other Linear "S" series transmitter contains a MODE switch.

The functions of the four MODE switch keys are:

KEY #1: STATUS SWITCH

The STATUS switch is used to enable or disable the transmitter's status timer. When the switch is in the *open* (OFF) position, the transmitter sends a **status** report to the SSR-32 every hour. This report updates the SSR-32, indicating the existence of the transmitter, the condition of the battery, and the state of the contact. When the switch is in the *closed* (ON) position, the transmitter does **not** send hourly **status** reports.

The STATUS switch **must** be in the *open* (OFF) position to use the transmitter on Zones 1-6.

CHANNEL SWITCH #					CHANNEL NUMBER
4	5	6	7	8	
OFF	OFF	OFF	OFF	OFF	1
OFF	OFF	OFF	OFF	ON	2
OFF	OFF	OFF	ON	OFF	3
OFF	OFF	OFF	ON	ON	4
OFF	OFF	ON	OFF	OFF	5
OFF	OFF	ON	OFF	ON	6
OFF	OFF	ON	ON	OFF	7
OFF	OFF	ON	ON	ON	8
OFF	ON	OFF	OFF	OFF	9
OFF	ON	OFF	OFF	ON	10
OFF	ON	OFF	ON	OFF	11
OFF	ON	OFF	ON	ON	12
OFF	ON	ON	OFF	OFF	13
OFF	ON	ON	OFF	ON	14
OFF	ON	ON	ON	OFF	15
OFF	ON	ON	ON	ON	16
ON	OFF	OFF	OFF	OFF	17
ON	OFF	OFF	OFF	ON	18
ON	OFF	OFF	ON	OFF	19
ON	OFF	OFF	ON	ON	20
ON	OFF	ON	OFF	OFF	21
ON	OFF	ON	OFF	ON	22
ON	OFF	ON	ON	OFF	23
ON	OFF	ON	ON	ON	24
ON	ON	OFF	OFF	OFF	25
ON	ON	OFF	OFF	ON	26
ON	ON	OFF	ON	OFF	27
ON	ON	OFF	ON	ON	28
ON	ON	ON	OFF	OFF	29
ON	ON	ON	OFF	ON	30
ON	ON	ON	ON	OFF	31
ON	ON	ON	ON	ON	32

Figure 8. Transmitter Channel Coding

KEY #2: RESTORE SWITCH

The RESTORE switch enables or disables the transmitter's capability to send a **restore** report. When the switch is in the *open* (OFF) position, the transmitter sends a **restore** report to the SSR-32 each time the contacts connected to the transmitter are returned from a faulted state to a normal state (door closed). When the switch is in the *closed* (ON) position, the transmitter will **not** send **restore** reports.

The RESTORE switch **must** be in the *open* (OFF) position to use the transmitter on zones that are **not** auto-restore.

KEY #3: DELAY SWITCH

The DELAY switch must be in the *closed* (ON) position, when the ST transmitter is used with the SSR-32.

If the transmitter is to be used on an exit/entry door, set the transmitter CHANNEL switch to activate an Exit/Entry Delay zone on the SSR-32 and connect that ZONE output to an Exit/Entry Delay zone on the control panel.

In this system the control panel and the SSR-32, not the transmitter, provides the delay.

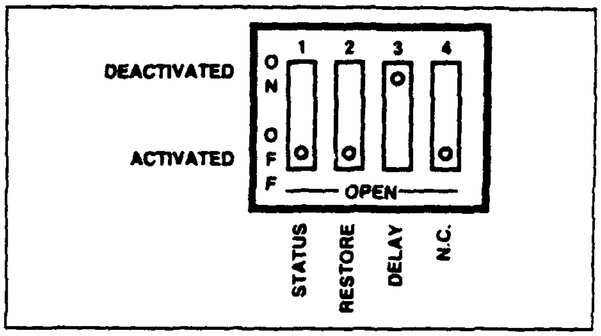


Figure 9. Typical MODE Switch Settings

KEY #4: NC SWITCH

When the NC switch is in the *open* (OFF) position, the transmitter is set for a normally **closed** loop.

When the NC switch is in the *closed* (ON) position, the transmitter is set for a normally **open** loop.

Up to 10 contacts with a maximum wire run of 50 feet may be connected to any one ST transmitter. (A twisted pair is recommended.) Wire multiple contacts in parallel for normally open, and in series for normally closed contacts.

In Figure 9 the MODE switches have been set with status activated, restore activated, no delay, and the loop normally closed.

7. INPUT/OUTPUT TERMINAL DESIGNATIONS

The SSR-32 uses two terminal blocks to connect the receiver to the control panel. It is very important to be sure the wiring is correct **before** applying any power to the system.

Figures 10 and 11 show the two terminal blocks (TB1 & TB2) and example control panel interconnections in detail.

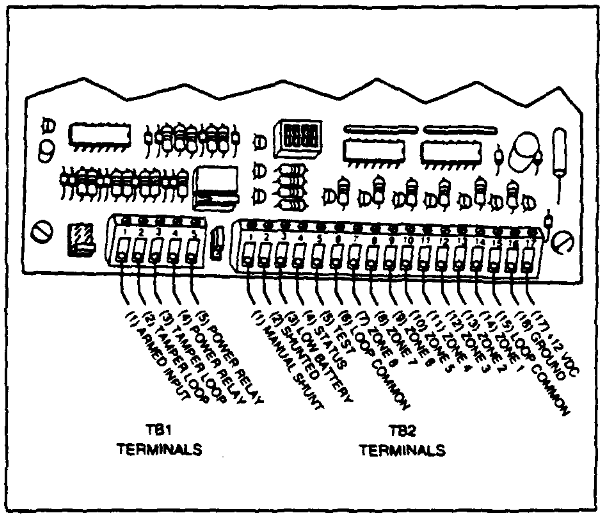


Figure 10. SSR-32 TB1 and TB2 Terminals

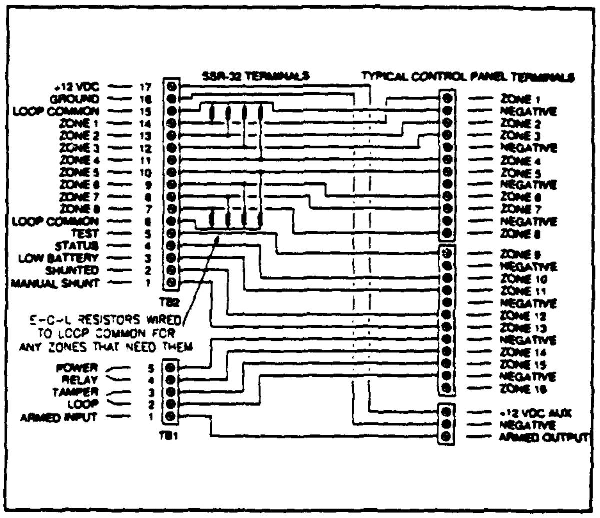


Figure 11. Typical SSR-32 to Control Panel Connections

8. RECEIVER INSTALLATION

The SSR-32 should be mounted on the wall above or next to the control panel. Generally, the higher the receiver is mounted above ground level the better the radio range will be.

PREPARATION

The SSR-32 has a spring-loaded tamper switch that, when activated, signals unauthorized access to the system circuits (see Figure 13). Set to activate when the case cover is removed, the tamper switch is normally closed and connected to the TAMPER LOOP terminals.

➡ *NOTE: Before working on a pre-existing installation, the tamper switch must be deactivated. This can be accomplished in either of two ways: (1) Power may be removed from the system by disconnecting the AC transformer and backup battery; or (2) the tamper loop can be jumpered out in the control panel.*

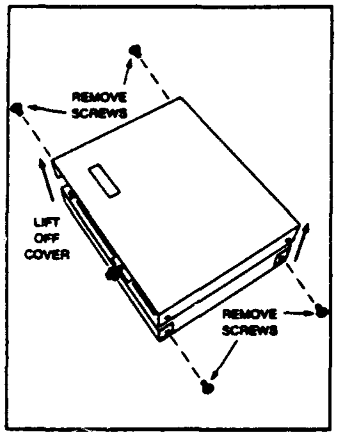


Figure 12. Removing the SSR-32 Case Cover

1. Remove the front cover of the case (see Figure 12).

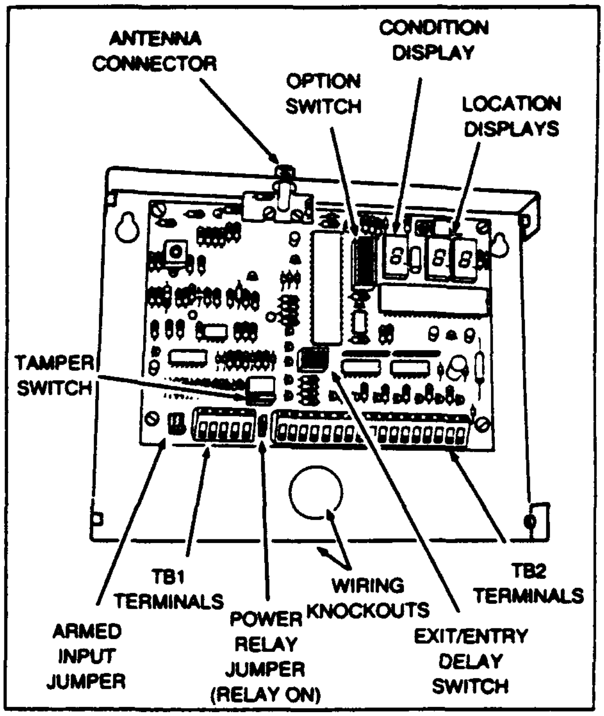


Figure 13. SSR-32 Circuit Board

2. Connect the SSR-32 to the control panel. The terminal block connections are described in detail in Section 7.
   - ✓ Connect GROUND (TB2 Terminal 16) to the negative terminal on the 12-volt 24-hour output from the control panel.
   - ✓ Connect +12-VOLT (TB2 Terminal 17) to the positive terminal on the 12-volt 24-hour output from the control panel.
   - ✓ Connect the ZONE outputs 1-8 (TB2 Terminals 7 through 14) to the zone input terminals on the control panel.
   - ✓ Connect the LOOP COMMON (TB2 Terminal 6) to a loop return on the control panel.
   - ✓ If the control panel uses end-of-line resistors, connect each resistor across the ZONE output terminals (TB2 7 through 14) and the LOOP COMMON (TB2 Terminals 6 or 15).
   - ✓ Connect the ARMED INPUT (TB1 Terminal 1) to the armed LED or opening/closing output on the control panel.
   - ✓ Connect the tamper loop on the control panel across the TAMPER LOOP terminals (TB1 Terminals 2 & 3) (optional).
   - ✓ Connect an external Manual Shunt switch (if shunting by channel is desired) across the Manual Shunt (TB2 Terminal 1) and GROUND terminals (TB2 Terminal 16).
   - ✓ For supervisory reporting, connect any or all of the four outputs (**SHUNTED, LOW BATTERY, STATUS, and TEST**) (TB2 Terminals 2 through 5) to unused control panel zone(s) or communicator input(s). Install end-of-line resistors across the outputs and LOOP COMMON if required.
   - ✓ For power supervision, connect the POWER RELAY terminals (TB1 Terminals 4 & 5) to a normally closed alarm loop or communicator input. Move the POWER RELAY JUMPER J2 (see Figure 13) to the RELAY ON position.
3. Set the ARMED INPUT JUMPER J1 (see Figure 14) to match the type of armed signal that the control panel provides.

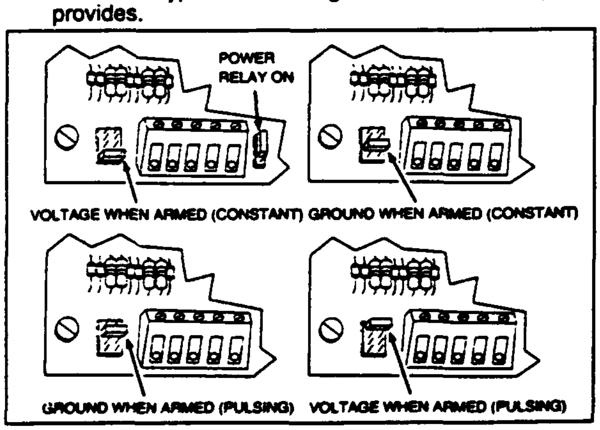


Figure 14. Armed Input Jumper Positions

➥ *NOTE: If the ARMED INPUT JUMPER is set for a pulsing armed signal, the control panel must be disarmed for at least ten seconds before rearming will clear the SSR-32 alarm memory.*

4. To apply power to the SSR-32, connect the control panel's AC transformer. **DO NOT connect the back-up battery until after the installation is complete.**

9. RECEIVER PROGRAMMING

In the procedure under subheading "Setting The Transmitter Channel and Zone Code," Page 9, a zone and unique channel code were assigned to each transmitter in the system. These transmitter codes now need to be programmed into the SSR-32's memory. This non-volatile memory will retain its information indefinitely without DC power. If the installer chooses to program the SSR-32 prior to installation, it can be disconnected at the programming site and transported to the job site without losing the memory. Also, if a control panel has a complete power failure, the SSR-32 will retain its memory.

➥ *NOTE: The control panel* **must** *be disarmed when programing the SSR-32.*

OPTION SWITCH

The OPTION Switch, as located in Figure 13, is used to control various setup and programming options. Refer to Figure 15 when setting the following OPTION Switch keys.

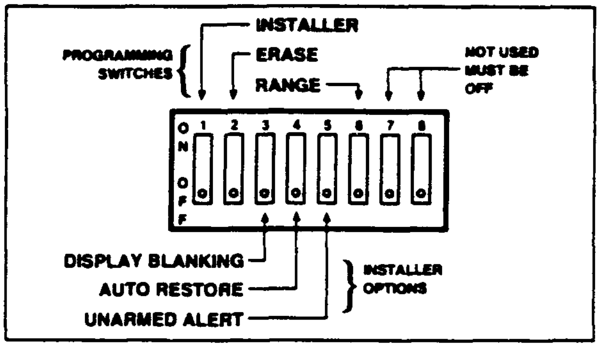


Figure 15. OPTION Switch

1. Set the RANGE switch (OPTION Switch key #6) and the INSTALLER switch (OPTION Switch key #1) to the ON position. Set the DISPLAY BLANKING switch (OPTION Switch key #3) to OFF.

➥ *NOTE: The RANGE switch reduces the receiver sensitivity by 15-20%. This gives the receiver a "worst-case" radio reception condition during set-up. This switch must be turned OFF after set-up.*

2. Set the ERASE switch (OPTION Switch key #2) to ON, then OFF. This will erase the memory and set up the SSR-32 for programming with the transmitters.

3. Log in all transmitters, one at a time, by pressing the test button on each transmitter. For ST-1 panic transmitters, simply press the pushbutton. For PIRs, walk through the detection pattern. Transmissions received while in this Channel Entry Mode will be entered and stored automatically in the SSR-32's memory. As each transmission is received, the SSR-32's display will indicate entry into the memory by showing an "E" on the *condition* display followed by the channel number on the *location* display (see Figure 16).

✱ **CAUTION! If duplicate transmitter channel codes are accidentally entered into the system while in the Channel Entry Mode, the SSR-32 will recognize only the last transmitter channel/zone code combination for that channel.**

➥ *NOTE: Enter codes from* **all** *transmitters during the same programming session. If, later, it is necessary to add additional transmitters,* **all** *of the transmitter codes must be re-entered as described above.*

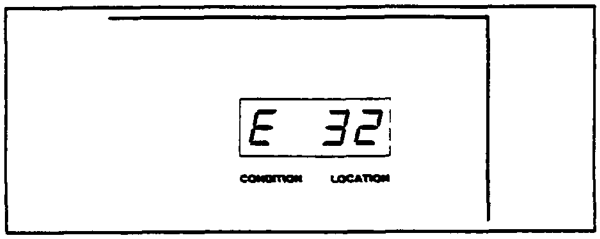


Figure 16. Display Indication in Entry Mode

AUTO-ENTRY

As an alternative to manual programming, the system design provides for automatic programming in conjunction with the reception of each transmitters initial **status** report. This can be accomplished by leaving the SSR-32 in the Channel Entry Mode for at least 1 hour, which is enough time to permit each transmitter to transmit a **status** report.

➥ *NOTE: Because portable ST-1 transmitters do not normally transmit a* **status** *report, their identification codes must still be entered manually.*

4. Return the INSTALLER switch (OPTION Switch key #1) to the OFF position. This action stores all new transmitter channel/zone information in the SSR-32's memory.

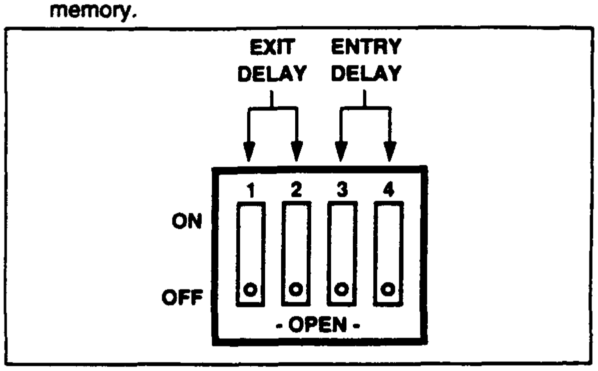


Figure 17. EXIT/ENTRY DELAY Switch

EXIT/ENTRY DELAY SWITCH

The EXIT/ENTRY DELAY Switch, as located in Figure 13, is used to control the exit and entry delay times. Refer to Figures 17, 18, and 19 when setting the following switch keys.

➡ *The zone outputs are not delayed, only the latching of the alarm memory display is delayed.*

☆ **EXIT DELAY (Keys #1 AND #2)**

Keys #1 and #2 can be set four possible ways to select different Exit Delay times. **To allow time for the Auto Shunt feature to activate, the SSR-32 Exit Delay time must be at least five seconds less than the control panel's Exit Delay**. Set keys #1 and #2 to select the proper delay time as shown in Figure 18.

☆ **ENTRY DELAY (Keys #3 AND #4)**

Keys #3 and #4 can be set four possible ways to select different Entry Delay Times. To coordinate the control panel's and the SSR-32's Entry Delay times, **the SSR-32's Entry Delay must be equal to or longer than the control panel's.** Set keys #3 and #4 to select the proper delay time as shown in Figure 19.

EXIT/ENTRY SWITCH KEY #		APPROXIMATE SSR-32 EXIT DELAY	RECOMMENDED CONTROL PANEL EXIT DELAY
1	2		
OFF	OFF	10 SECONDS	15 SECONDS
OFF	ON	20 SECONDS	25 SECONDS
ON	OFF	30 SECONDS	35 SECONDS
ON	ON	40 SECONDS	45 SECONDS

Figure 18. Exit Delay Switch Settings

EXIT/ENTRY SWITCH KEY #		APPROXIMATE SSR-32 ENTRY DELAY	RECOMMENDED CONTROL PANEL ENTRY DELAY
3	4		
OFF	OFF	20 SECONDS	15 SECONDS
OFF	ON	30 SECONDS	25 SECONDS
ON	OFF	40 SECONDS	35 SECONDS
ON	ON	50 SECONDS	45 SECONDS

Figure 19. Entry Delay Switch Settings

10: INSTALLER OPTIONS

DISPLAY BLANKING SWITCH (OPTION Key #3)

Set key #3 to ON to blank the display when the system is armed. With key #3 set to OFF, the display is always active.

AUTO RESTORE (OPTION Key #4)

Setting key #4 to ON automatically restores transmitter **alarm** signals sent on channels programmed for Zones 3, 4, 5, and 6. With key #4 OFF, transmitters must send a **restore** signal to clear the zone.

UNARMED ALERT (OPTION Key #5)

Setting key #5 to ON causes the alarm memory display to latch on transmitter **alarm** signals sent on channels programmed for Zones 6, 7, and 8 regardless if the system is armed or disarmed. With key #5 OFF, these zones will only latch the alarm memory while the system is armed.

MANUAL SHUNT BYPASS FEATURE (OPTIONAL)

The SSR-32 receiver incorporates an automatic as well as a manual shunt feature. This feature makes it possible to bypass (shunt) one or more transmitter channels so that the zone they are programmed to operate will not be activated if the transmitter is faulted.

Because most control panels **will not** let the user arm the system when a loop is faulted, this feature is useful for shunting doors or windows that are intended to be left open or to force-arm the control panel. When a transmitter is shunted, the SSR-32 will ignore **alarm** and **restore** reports, but will still acknowledge **status** and **low battery** reports from shunted transmitters.

For manual shunting, wire a user-accessible toggle switch or normally open pushbutton across the MANUAL SHUNT input (TB2 Terminal 1) and the GROUND (TB2 Terminal 16). When the switch is closed, any channel that is in the open ("O") condition will be set into the shunted ("S") condition. This shunted condition will remain until the Manual Shunt switch is opened.

By using a momentary pushbutton, faulted transmitters can be temporarily shunted while the button is held down to allow arming of the control panel. Then, as soon as the panel is armed, the button can be released. The SSR-32's Auto Shunt will then take over if any transmitters remain faulted after the Exit Delay expires.

Whenever the Manual Shunt switch is activated, the SHUNTED output (TB2 Terminal 2) will activate. This output can be used to trigger a communicator zone to indicate an abnormal closing (arm over fault).

EXTERNAL ANTENNA

The SSR-32 is equipped with an "F" type antenna connector designed to connect with Linear's EXA-1000 external antenna. This antenna can be used to remote the receiver's RF input and to possibly extend the radio range in difficult installations where the receivers stock antenna is insufficient.

11. SYSTEM CHECK-OUT

VERIFY MODE

The Verify Mode has two functions. When the receiver is first set to verify, the LED display sequentially shows each of the zone/channel combinations currently programmed into the memory. This ensures that the proper channels are assigned to the correct zones (see Figure 20). The Verify Mode is then used to range check the transmitters from their respective locations.

To set the SSR-32 to the Verify Mode, set the ERASE switch (OPTION Switch key #2) to OFF, and the INSTALLER switch (OPTION Switch key #1) to ON. The SSR-32 will not go into the Verify Mode if the ERASE switch is ON or the control panel is armed.

➡ *NOTE: If no transmitters are logged in the SSR-32 memory, only a continuous series of dashes will appear on the display.*

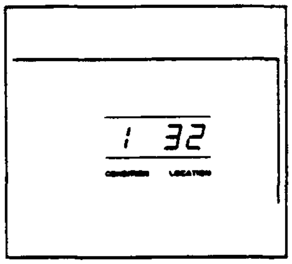


Figure 20. Display in Verify Mode (Zone 1, Channel 32)

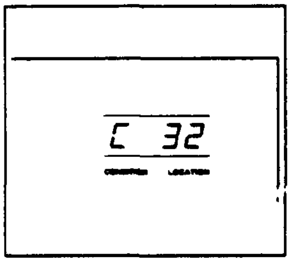


Figure 21. Display in Verify Mode (Range Check on Channel 32)

RANGE CHECK

1. Move the transmitters to the desired test locations.

   The transmitters should be temporarily mounted in case they have to be moved later. Double-stick tape works well for this.

CAUTION! DO NOT mount any transmitter on a metal surface. Some windows have a concealed metal flashing around the frame. Be aware of this and other hidden metal objects. If such a situation is encountered, install the contact on the window frame and use enough wire to locate the transmitter on the wall away from the frame.

2. While the SSR-32 is still in the Verify Mode, trigger a test transmission from each transmitter. If the transmitter is within radio range, the SSR-32 will replace that transmitter's zone number on the *condition* display with a "C" for "checked" (see Figure 21). If the transmitter is out of radio range, no "C" will appear. If the transmitter does not range check from the desired location, either experiment by moving the transmitter to different areas and testing, or use an AC voltmeter to make field strength measurements at the receiver test points to determine the best possible location for the transmitter.
3. After completing range checking for all of the transmitters, return the INSTALLER switch (OPTION Switch key #1) and the RANGE switch (OPTION Switch key #6) to the OFF position.

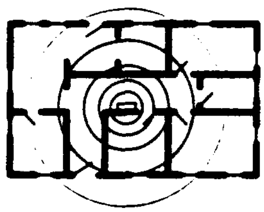
12. FINAL TESTING

1. With the control panel disarmed, open a protected door. The transmitter should send an **alarm** report, causing an "O" to be shown on the *condition* display. At the same time the channel number should be shown on the *location* display.
2. Close the same protected door. The transmitter should send a **restore** report, causing the "O" to revert to the moving dashes indication.
3. Arm the control panel with the siren or bell and telephone line disconnected and wait for the Exit Delay to expire. Open a protected exit/entry door and wait for the Entry Delay to expire. This procedure should result in an "O" alternating with an "F" on the *condition* display. The channel number of the transmitter should show on the *location* display.
4. Close the same protected door. The "O" should be removed from the display but the "F" should remain. The channel number should still be on the *location* display.
5. Open then close any other protected door. This procedure should result in an "A" alternating with an "F" on the *condition* display. The channel number of both transmitters should alternate on the *location* display. The first transmitter with an "F", and the second transmitter with an "A".
6. Disarm the control panel. The "F" and "A" and channel numbers should remain on the display. The "F" and "A" remain to give the SSR-32 an alarm memory. This is so the customer or installer can look at the display after the system is disarmed and determine which transmitter(s) has gone into alarm since the last time the control panel was armed.
7. Rearm the control panel. The "F" and "A" will be erased and the display should return to dashes.

➡ *NOTE: If the armed input jumper is set for a pulsing armed signal, the control panel must be disarmed for at least 10 seconds before re-arming will clear the SSR-32 memory. This prevents a blinking armed LED from resetting the alarm memory.*

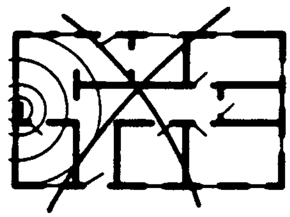
8. Disarm the control panel to complete final testing.

13. INSTALLATION TIPS



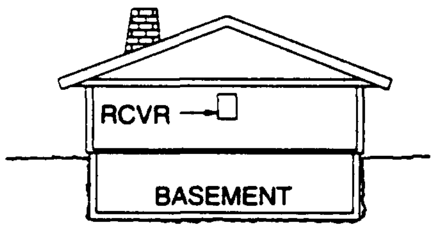
RIGHT

CENTRALLY LOCATE RECEIVER



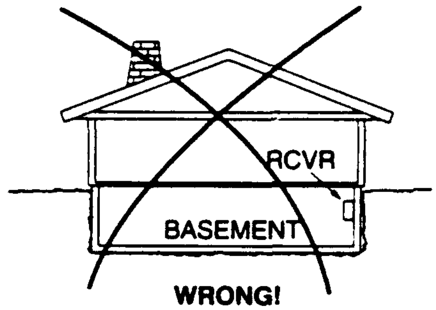
WRONG!

TRANSMITTERS AT THE OTHER END OF HOUSE MIGHT BE TOO FAR AWAY



RIGHT

MOUNT RECEIVER AS HIGH ABOVE EARTH LEVEL AS POSSIBLE

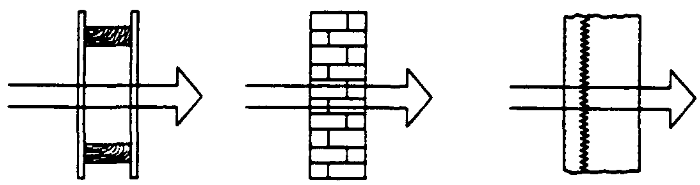


WRONG!

LOCATING A RECEIVER BELOW EARTH LEVEL WILL IMPAIR RANGE

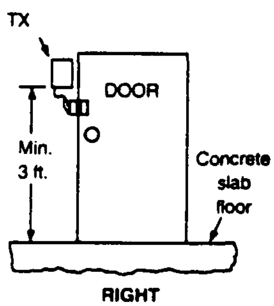
INSTALLATION TIPS (continued)

90% - 100% OF FULL POWER | 65% - 95% OF FULL POWER | 10% - 70% OF FULL POWER

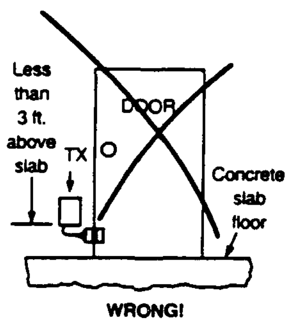


WALLBOARD AND WOOD STUDS | LIGHT CONCRETE OR BRICK | CONCRETE WITH STEEL REINFORCEMENT OR METAL LATH AND PLASTER

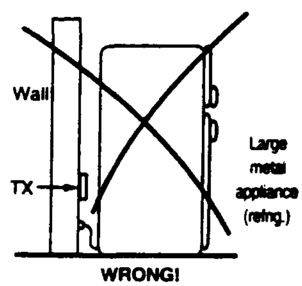
CONSTRUCTION MATERIALS AFFECT RADIO RANGE



RIGHT



WRONG!



WRONG!

14 RECEIVER SPECIFICATIONS

Coding Technique	Pulse position A1 modulation at 150 bits per second. Two 21-bit words are required for a valid transmission
Number of Codes	256 System codes, 32 Channel codes, 8 Zone codes
RF Carrier Frequency	303.875 MHz 315.000 MHz
3 db Bandwidth	2 MHz
Power Requirements	12 VDC, Standby and during display blanking 25 mA, Operating 200 mA maximum
Output Rating	Open collector, 100 mA maximum, 12 Volts maximum per output
Temperature Range	+ 32 to + 120 degrees F (0 to + 49 degrees C)
Size	Approximately 6-1/2 x 7-3/4 x 1-1/4 inches (165.1 x 196.9 x 31.8 mm)
Weight	1.5 Lbs. (.68 Kg)

15 INDEX

LINEAR LIMITED WARRANTY

This Linear product is warranted against defects in material and workmanship for twelve (12) months. The Warranty Expiration Date is labeled on the product. **This warranty extends only to wholesale customers** who buy direct from Linear or through Linear's normal distribution channels. **Linear does not warrant this product to consumers.** Consumers should inquire from their selling dealer as to the nature of the dealer's warranty, if any. **There are no obligations or liabilities on the part of Linear corporation for consequential damages arising out of or in connection with use or performance of this product or other indirect damages with respect to loss of property, revenue, or profit, or cost of removal, installation, or reinstallation.** All implied warranties, including implied warranties for merchantability and implied warranties for fitness, are valid only until Warranty Expiration Date as labeled on the product. **This Linear Corporation Warranty is in lieu of all other warranties express or implied.**

For warranty service on Linear equipment return product, at sender's expense to:

Linear Corporation
2350 Camino Vida Roble
Carlsbad, CA 92009
Attention: Repairs Department
Ph# (800) 392-0123

IMPORTANT !!!

Linear radio controls provide a reliable communications link and fill an important need in portable wireless signalling. However, there are some limitations which must be observed.

* For U.S. installations only: The radios are required to comply with FCC Rules and Regulations as Part 15 devices. As such, they have limited transmitter power and therefore limited range.
* Receivers may be blocked by radio signals that occur on or near their operating frequencies, regardless of code settings.
* A receiver cannot respond to more than one transmitted signal at a time.
* Infrequently used radio links should be tested regularly to protect against undetected interference or fault.
* A general knowledge of radio and its vagaries should be gained prior to acting as a wholesale distributor or dealer, and these facts should be communicated to the ultimate users.

FCC NOTICE

This equipment generates and uses radio frequency energy and if not installed and used properly, that is, in strict accordance with the manufacturer's instructions, may cause interference to radio and television reception. It has been type tested and found to comply with the limits for a Class B computing device in accordance with specifications in Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference in a residential installation. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

* Re-orient the television or radio receiving antenna.
* Relocate the SSR-32 with respect to the receiver.
* Move the SSR-32 away from the receiver.
* Power the control panel from a different AC outlet.

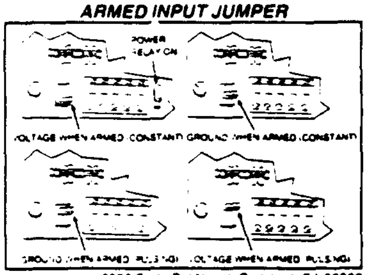
If necessary, the user should consult the installer or an experienced radio/television technician for additional suggestions. The user may find the following booklet prepared by the Federal Communications Commission helpful:

"How to Identify and Resolve Radio-TV Interference Problems" This booklet is available from the U.S. Government Printing Office, Washington D.C. 20402, Stock # 004-000-00345-4.

TRANSMITTER ZONE CODING

ZONE	TX CHANNEL SWITCH # 1	2	3	EX&ENT DELAY (STD)	AUTO RESTORE (STD)	AUTO RESTORE (OPT)	UN-ARM ALERT (OPT)
1	OFF	OFF	OFF	✔			
2	OFF	OFF	ON	✔			
3	OFF	ON	OFF	✔		✔	
4	OFF	ON	ON			✔	
5	ON	OFF	OFF			✔	
6	ON	OFF	ON			✔	✔
7	ON	ON	OFF		✔		✔
8	ON	ON	ON		✔		✔

ARMED INPUT JUMPER



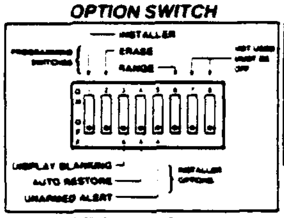
2055 Corte Del Nogal, Carlsbad, CA 92009
Technical Services: (800) 392-0123 • CA (800) 321-1845
(619) 438-7000 • FAX (619) 438-7043

CHANNEL CODING

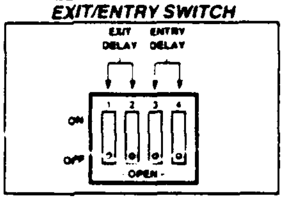
CH. #	TX CHANNEL SWT # 4	5	6	7	8
1	OFF	OFF	OFF	OFF	OFF
2	OFF	OFF	OFF	OFF	ON
3	OFF	OFF	OFF	ON	OFF
4	OFF	OFF	OFF	ON	ON
5	OFF	OFF	ON	OFF	OFF
6	OFF	OFF	ON	OFF	ON
7	OFF	OFF	ON	ON	OFF
8	OFF	OFF	ON	ON	ON
9	OFF	ON	OFF	OFF	OFF
10	OFF	ON	OFF	OFF	ON
11	OFF	ON	OFF	ON	OFF
12	OFF	ON	OFF	ON	ON
13	OFF	ON	ON	OFF	OFF
14	OFF	ON	ON	OFF	ON
15	OFF	ON	ON	ON	OFF
16	OFF	ON	ON	ON	ON
17	ON	OFF	OFF	OFF	OFF
18	ON	OFF	OFF	OFF	ON
19	ON	OFF	OFF	ON	OFF
20	ON	OFF	OFF	ON	ON
21	ON	OFF	ON	OFF	OFF
22	ON	OFF	ON	OFF	ON
23	ON	OFF	ON	ON	OFF
24	ON	OFF	ON	ON	ON
25	ON	ON	OFF	OFF	OFF
26	ON	ON	OFF	OFF	ON
27	ON	ON	OFF	ON	OFF
28	ON	ON	OFF	ON	ON
29	ON	ON	ON	OFF	OFF
30	ON	ON	ON	OFF	ON
31	ON	ON	ON	ON	OFF
32	ON	ON	ON	ON	ON

Linear
A NORTEK COMPANY

OPTION SWITCH



EXIT/ENTRY SWITCH



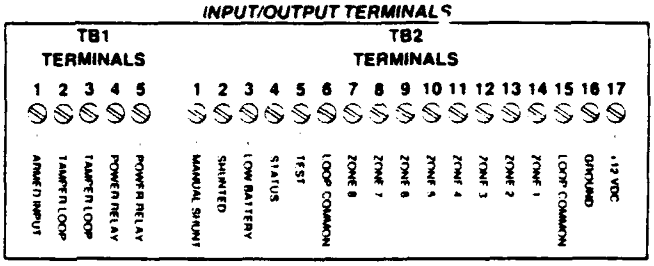
SSR-32 PROGRAMMING SUMMARY

	OPTION SWITCH ACTION	INDICATION
1	Disarm control panel	Moving dashes
2	Set System, Zone, & Chan. codes on Tx's	Moving dashes
3	Turn Installer (#1) & Range (#6) ON	Verify mode of old prog.
4	Turn Erase (#2) ON then OFF	Moving dashes
5	Press Test button on each Tx	Entry of each Tx
6	Turn Installer (#1) OFF then ON	Verify mode of new prog.
7	Test each Tx from final location	Check range of each Tx
8	Turn Range (#6) & Installer (#1) OFF	Ready to run
9	Test system for proper operation	Open door/window = "O"

EXIT/ENTRY SWITCH KEY # 3	4	APPROXIMATE SSR-32 ENTRY DELAY	RECOMMENDED CONTROL PANEL ENTRY DELAY
OFF	OFF	20 SECONDS	15 SECONDS
OFF	ON	30 SECONDS	25 SECONDS
ON	OFF	40 SECONDS	35 SECONDS
ON	ON	50 SECONDS	45 SECONDS

EXIT/ENTRY SWITCH KEY # 1	2	APPROXIMATE SSR-32 EXIT DELAY	RECOMMENDED CONTROL PANEL EXIT DELAY
OFF	OFF	10 SECONDS	15 SECONDS
OFF	ON	20 SECONDS	25 SECONDS
ON	OFF	30 SECONDS	[illegible] SECONDS
ON	ON	40 SECONDS	45 SECONDS

INPUT/OUTPUT TERMINALS



25

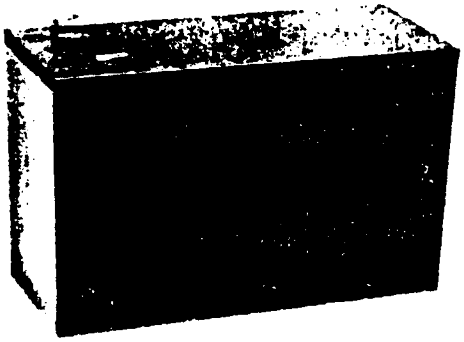
Summary of SSR-32 Programming Instructions

	ACTION (USING SSR-32 OPTION SWITCH)	EXAMPLE INDICATION	DESCRIPTION
1.	Disarm control panel	- - -	Dancing dashes
2.	Set System, Zone, and Channel codes on Tx's	- - -	Dancing dashes
3.	Turn Installer switch (#1) and Range switch (#6) ON	4 32	Verify mode of old program
4.	Turn Erase switch (#2) ON then OFF	- - -	Dancing dashes
5.	Press Test button on each Tx	E 32	Entry of each Tx
6.	Turn Installer switch (#1) OFF then ON	4 32	Verify mode of new program
7.	Press Test button on each Tx from final location	C 32	Check range of each Tx
8.	Turn Range switch (#6) and Installer switch (#1) OFF	- - -	Ready to run
9.	Test system for proper operation	O 32	Open door/window shows "O"

Linear
A NORTEK COMPANY

2055 Corte Del Nogal
Carlsbad, CA 92009
(619) 438-7000 • (800) 421-1587
CA (800) 321-1845 • FAX (619) 438-7043
Customer/Technical Service: (800) 392-0123

RECHARGEABLE GEL-TYPE BATTERY



FEATURES:

- o Suspended Electrolyte
- o Leak Proof
- o Easy Handling
- o Overcharge Protection
- o Cycle or Float Applications
- o High Discharge Rate
- o Compact and Rugged
- o Extended Shelf Life

Part Number	Nominal Voltage	Rated Capacity @ 20 HR. Rate (amp. hours)	20 HR Discharge Rate (mA)	Dimensions (L x W x H*) in. (mm.)	Weight lbs. (kg.)	Terminals
400-600-00	6	2.6	130	5.28x1.34x2.56 (134x34x65)	1.28 (0.58)	See Note 1
400-602-00	6	20.0	1000	6.18x3.27x4.92 (157x83x125)	8.16 (3.70)	See Note 3
400-603-00	6	1.0	50	2.00x1.65x2.20 (51x42x56)	0.62 (0.28)	See Note 1
400-604-00	6	0.5	--	1.92x1x2.25 (49x25x57)	0.3 (0.14)	
400-700-00	12	5.0	250	5.96x2.56x3.89 (152x65x99)	5.10 (2.30)	See Note 1
400-701-00	12	20.0	1000	6.5x5.0x6.7 (175x166x125)	17.60 (8.00)	See Note 2
400-702-00	12	2.6	130	7.68x1.85x2.95 (195x47x75)	2.86 (1.30)	See Note 1
400-703-00	12	1.2	60	5.95x2.56x3.7 (100x42x56)	1.24 (0.56)	See Note 1
400-704-00	12	6.5	325	5.95x2.56x3.86 (151x65x98)	5.72 (2.60)	See Note 1

NOTE 1: Quick Disconnect Tabs, 0.187" x 0.032". Mate with Amp, Inc. Faston "187" series.

NOTE 2: Quick Disconnect Tabs, 0.250" x 0.032". Mate with Amp, Inc. Faston "250" series.

NOTE 3: Nut and Bolt Connectors

*Height over terminal

Monaco Enterprises INC.
E. 14820 SPRAGUE AVE., P.O. BOX 14129, SPOKANE, WASHINGTON 99214 (509) 926-6277

ULTRAVIOLET FLAME DETECTORS

General.

The Monaco Open Area Ultraviolet Flame Detectors are designed to operate on standard 12 volts DC or 24 volts DC.

The detector assembly is a compact unitized package containing the detection tube, encapsulated solid state electronic circuitry and a dry contact Form C (SPDT) alarm relay. The detector locks in on alarm, and an alarm light illuminates the detection tube for easy identification of the unit in the alarm state. Detector reset is achieved by momentarily interrupting power to the unit.

A 3-second time delay is built in to minimize response to lightning flashes, welding arc, sparks, etc.

The indoor unit is contained in a general-purpose enclosure, and is for indoor use only. It mounts on a standard 4-inch octagonal electrical junction box (not supplied).

The outdoor unit is contained in an explosion proof enclosure meeting all requirements for NEC Class I Groups C and D, Class II Groups E, F, and G and Class III hazardous locations and is available, on special order, for Class I Group B service. It complies will all requirements for NEMA 3, 7CD, 9EFG and 12 enclosures and is suitable for indoor or outdoor applications.

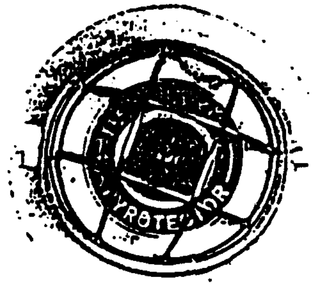
Theory of Operation.

Monaco's Ultraviolet Flame Detectors operate on the Geiger-Muller principle utilizing an Ultraviolet-sensitive photocathode within a fused silica envelope.

When exposed to ultraviolet radiation the photocathode emits photo-electrons which ionize the inert gas within the tube. This initiates a current flow which produces an alarm signal.

ORDERING INFORMATION

Part Number	Description
725-201-00	Ultraviolet Flame Detector, Indoor, 12Vdc
725-301-00	Ultraviolet Flame Detector, Indoor, 24Vdc
725-202-00	Ultraviolet Flame Detector, Outdoor, 12Vdc
725-302-00	Ultraviolet Flame Detector; Outdoor, 24 Vdc



Part Number 725-201-00

Cone of Vision.

The indoor detector has a 180° cone of vision. Relative sensitivity is greatest at a viewing angle of 45° either side of the head-on axis. At angles greater than 45°, sensitivity decreases linearly to 40% of head-on at 90° from head-on axis. See Figure 1. The outdoor detector's cone of vision is illustrated in Figure 2.

Sensitivity.

Detector response time is a product of fire size and proximity of the detector to the fire. Greater distances and smaller fires yield somewhat slower responses.

Typical detector proximity-fire size-response time characteristics are as follows:

Nominal Response Times

Fire Size	Distance		
	12 Ft.	22 Ft.	30 Ft.
6" diameter hydrocarbon fire	3 sec.	6 sec.	N/A
12" diameter hydrocarbon fire	3 sec.	3 sec.	6 sec.

Calculation of detector response to given fire sizes and distances can be predetermined by application of the inverse square law theory - e.g. - quadrupling the fire size area produces equal response time at twice the distance.

The outdoor detector is approximately 10% less sensitive. For example, a 3-second response time is achieved at 10 ft., rather than 12 ft., in detecting a 6" hydrocarbon fire.

Application.

The Ultraviolet Flame detector is essentially "solar-blind", that is it does not respond to normal ambient light conditions such as sunlight, incandescent or fluorescent lighting. It is highly sensitive to the ultraviolet portion of the energy radiated by all types of flames, including those produced by flammable liquids and gases. It is therefore ideally suited for general open area flame detection.

F69

Outdoor Applications.

The Outdoor detector has a controlled cone of vision which provides the capability to orient the detector so that its field of view is limited to the area or location of desired monitoring without undue exposure to the horizon or unwanted sources of ultraviolet radiation beyond the are of protection.

The Ultraviolet Flame detector is essentially solarblind; however, for complete safety it is recommended that detectors installed outdoors be so located or shielded that the detector element is not exposed to a direct "view" of the sun.

Special Considerations.

To insure proper detector operation, the quartz window and/or sensing tube surface must be kept clean and totally free of film at all times. Caution should be exercised in the cleaning of the sensing tube with absolute minimum pressure applied.

Cutting and welding within any Ultraviolet Flame detector's cone of vision may cause spurious alarms. Therefore, it is suggested that the detection system be de-energized during these activities.

SPECIFICATIONS	
Electrical	
Operating Voltage Range	12 - 16Vdc for 12Vdc Unit 22 - 27Vdc for 24Vdc Unit
Current (Standby)	10mA max at 12Vdc 12mA max at 24Vdc
Current (Alarm)	125mA max at 12Vdc 100mA max at 24Vdc
Relay Contact Rating	1A at 26Vdc
Detection	
Spectral Range	1700 to 2900 angstroms
Peak Spectral Response	2100 angstroms
Environmental	
Temperature Range	-25°C to 60°C (-13°F to 140°F)
Humidity	90% RH
Mechanical	
Enclosure Type	
Part Number 725-201-00 and 725-301-00	General purpose painted steel, with protective cage, and total encapsulation of electronics.
Part Number 725-202-00 and 725-302-00	Explosion proof housing with ¾" NPT female hub(s) (NEC Class 1, Groups C and D; Class II, Groups E, F, and G; Class III)
Dimensions	
P/N 725-201-00/725-301-00	4.09 Diameter, 3" High
P/N 725-202-00/725-302-00	Length—6.76, Width—2.75, Height—4.75
Weight	
P/N 725-201-00/725-301-00	¾ pounds
P/N 725-202-00/725-302-00	3¾ pounds

Factory Mutual Approved.

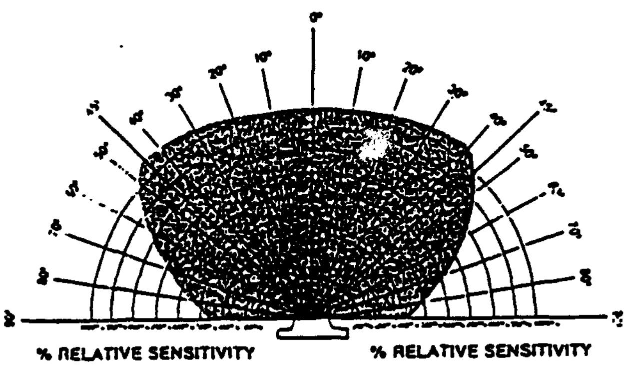


Figure 1

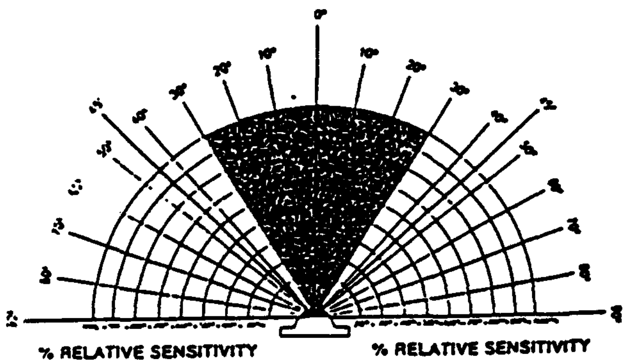
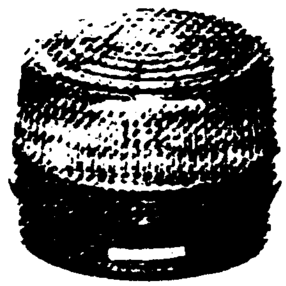


Figure 2

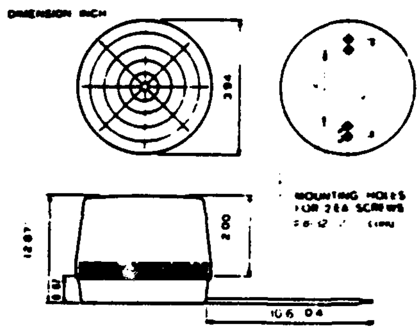
STROBES

FEATURES

- Solid state circuitry/xenon strobe tube.
- Polycarbonate lens, removable to facilitate flush mounting or color change.
- Clear thermoplastic strobe tube guard.
- Black textured thermoplastic base.
- Available in either 12 Vdc or 24 Vdc versions.
- Reversed polarity will not damage circuit. No. 22 AWG input leads, 10 inches long.
- Operable over – 40° to 85°C temperature range.
- Circuitry and strobe tube protected by thermoplastic guard sealed to housing.
- Raintight construction.
- 70,000 candle power.
- Red, amber, and clear lense colors available – specify color desired.



California State Fire
Marshal Approved



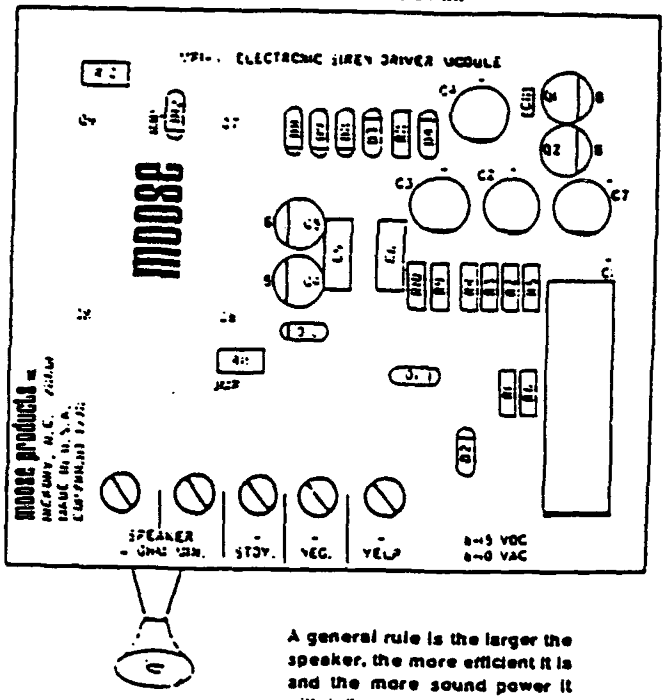
ORDERING INFORMATION

Part Number	Input Voltage	Input Current	Flash Rate	Color
367-002-00	12 VDC	180 mA ± 20%	60-100/min	Clear
367-003-00	12 VDC	180 mA ± 20%	60-100/min	Amber
367-004-00	12 VDC	180 mA ± 20%	60-100/min	Red
367-005-00	24 VDC	125 mA ± 20%	60-100/min	Clear
367-006-00	24 VDC	125 mA ± 20%	60-100/min	Amber
367-007-00	24 VDC	125 mA ± 20%	60-100/min	Red
369-005-00	Surface Mount Stainless Plate			
665-000-00	Std. 4S Box			

Siren Driver Module

MPI-11

Board size 3.12 in. X 3.81 in.



A general rule is the larger the speaker, the more efficient it is and the more sound power it will deliver.

Features

6 to 12 Volt AC or DC
Powers up to Four Speakers
Two Channels: Yelp and Steady
Steady Overrides Yelp

Speaker Wire

Under 150 feet — 18 gauge wire
Over 150 feet — 16 gauge wire

Speaker

@ 6 volts — 5 watt speaker minimum
@ 12 volts — 15 watt speaker minimum

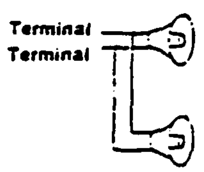
Specifications

MPI-30 Speaker	Load	Voltage	Current Drain	Sound Level
1 Speaker	8 ohm	6	500 MA	111 dB at 10 feet
2 Speakers	4 ohm	6	1.0 Amp	113 dB at 10 feet
1 Speaker	8 ohm	12	1.25 Amp	114 dB at 10 feet
2 Speakers	4 ohm	12	2.5 Amp	118 dB at 10 feet

MPI-30 Speaker used in determining above specifications.

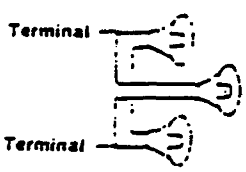
2 SPEAKERS

4 ohms



3 SPEAKERS

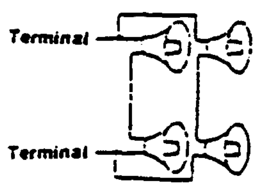
8 ohms



Using three speakers this speaker will be louder than the other two speakers.

4 SPEAKERS

8 ohms



This is a suggested speaker hookup pattern using 8 ohm speakers.

Monaco Enterprises INC.

E. 14820 SPRAGUE AVE., P.O. BOX 14129, SPOKANE, WASHINGTON 99214 (509) 926-6277

APPLICATION

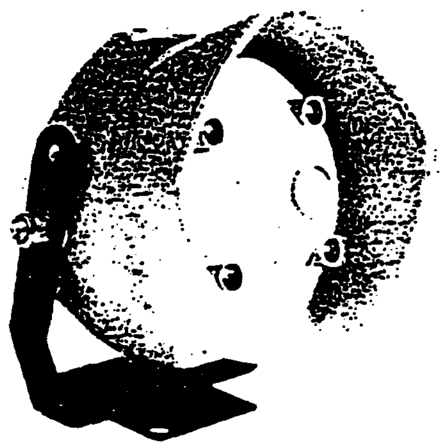
The MPI-34 Is A Compact, High Powered Siren Speaker. The 50 Watt Peak Rating Of This Small Speaker Will Deliver A Lot Of Sound In Locations That Were Never Possible With Conventional Speakers.

SPECIFICATIONS

- Rated 30-Watts/50 Watt Peak
- 8 Ohms
- Acoustic Pressure Of 120 Decibels At 10 Feet
- Measures:
  (1) 3 Inches Deep
  (2) 4 1/8 Inches Across Bell
- Two Piece Quick Connect Bail Type Mounting At Any Angle.
- High Impact Plastic
- Weight: Approximately 2 Pounds
- Frequency Response: 800 To 5500 Hz
- Heavy Duty Magnet
- Heavy Duty Diaphragm

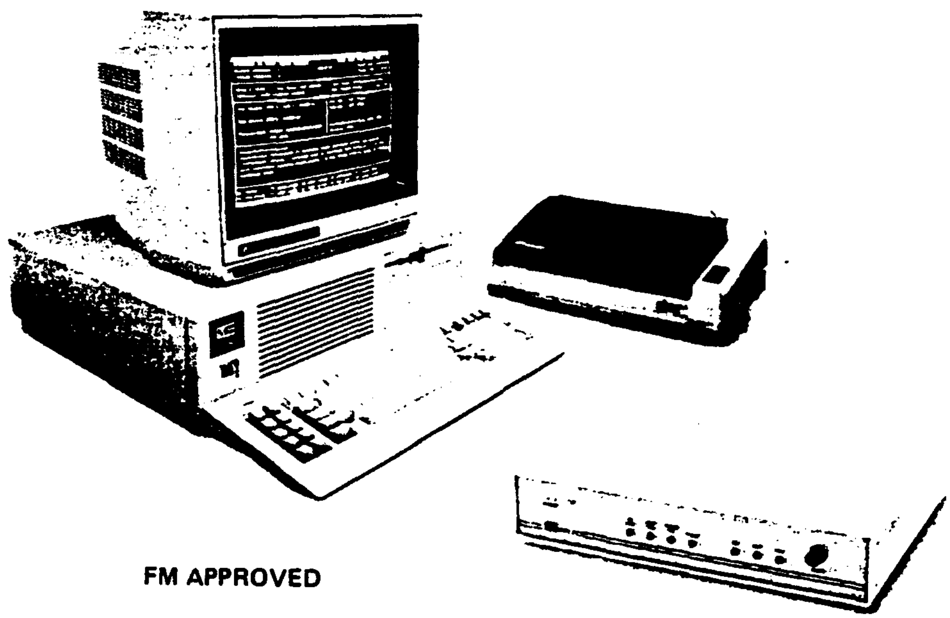
FEATURES

- Unique Bell Design For Louder Sounds
- Quality Tested
- Compact Size
- Non-Corrosive Housing
- Easy Mounting
- Outdoor Weather Resistant
- Quick Disconnect Mounting Foot



Monaco Enterprises INC.
E. 14820 SPRAGUE AVE., P.O. BOX 14129, SPOKANE, WASHINGTON 99214 (509) 926-6277

D-500 PLUS RADIO ALARM SYSTEM



FM APPROVED

FEATURES

- Software controlled receiving, recording and display system
- Identifies zone alarms and troubles, restorations and transceiver status
- Reports received from remote building transceivers via encoded VHF radio transmissions
- Radio communications supervised via automatic polling of all transceivers at user selected intervals; whole system or specific transceiver tests can be manually initiated
- User assigned BT2 and zone reporting range allow redundant and dual system operation
- Zone alarm test capability from central Computer
- Compatible with all Monaco BT2 Building Transceivers
- Automatic log of all system activity; selectable printout of Alarm Cards and reports
- Detection of transmissions on the system frequency and "listen in" capability to identify source
- Optional hardwired input/audible output for protection of receiving equipment location
- Dispatch information displays:
  - –Apparatus Status, Daily Notes, Call Directory
  - –Alarm Cards including location, response, water supply, hazards, alarm equipment and pre-plans
  - –3000 Fire, Security and Auxiliary Zone Cards (Refer to BT2's for zone reporting limits)
  - –60 Aircraft and 60 Non-Zone Emergency Cards
  - –Full color monitor for color-coded displays
  - –Automatic or manual Alarm Card display
  - –User assigned priorities for Alarm Card display from the alarms/troubles pending buffer
- Information Management Report Capability:
  - –Alarm/Trouble history by type (Zone, Aircraft, Non-Zone Emergency or BT2) for specified time spans
  - –Current zone alarms and troubles
  - –Current BT2 troubles
  - –BT2 Test Cycle reply status
  - –Lists of all Cards in the user's data base
- 4 or 24 hour emergency standby power provided in accordance with NFPA 72D
- Complies with NFPA 72D and 1221

F1

D-500 PLUS RADIO ALARM SYSTEM

The D-500 Plus provides all the functions of an alarm receiving system plus Computer Aided Dispatch information and system management reports. Alarm and trouble reports are transmitted from protected buildings to central receiving equipment on radio frequencies. This eliminates the need for acquiring, installing and maintaining land lines.

Each radio transceiver reports local system events to the central receiving equipment. The system can identify:

- fire alarms, security alarms, or auxiliary alarms
- zone troubles
- zone input return to normal
- ac power failure to the transceiver
- low battery at the transceiver
- transceiver enclosure tamper

The radio signals are received by the RF Modem (RFM-5000). This is a microprocessor controlled interface which converts the coded signals to standard RS-232C protocol and vice versa for connecting the radio system with a host computer. Communications between the Central Processing Unit and Modem are supervised. The Modem processes automatic and manual self tests. LED's on the Modem indicate comm fail, self test, ac power, transmit, receive and carrier detect.

When the Central Processing Unit receives the decoded signal from the RFM-5000, it automatically displays an Alarm Card for the zone in alarm. Alarm Cards may also be displayed manually for zones, aircraft emergencies and non-zone emergencies. Displays of apparatus status, daily notes and a call directory are also available. Apparatus is automatically dispatched from the Alarm Card. The displays are on an eight-color monitor, color coded for easy identification.

All system information is entered by the user so it can be tailored to the specific installation. Information is easily input and updated with functions selected from displayed menus. Any operation which changes the user data base is password protected to prevent unauthorized changes. The system operating program and user data base are stored in a hard disk.

Radio communications are supervised with an interrogation routine. The RF Modem calls all building transceivers at intervals selected by the user. All or specific transceivers can be interrogated manually at any time. The transceivers reply with current status and the CPU generates a report listing all transceiver test results. The interrogation cycle is limited to a user selected range of transceiver and zone addresses. The operation takes place in the background so all other program functions are available and the cycle is not interrupted by any other system activity.

All D-500 Plus activity is automatically logged on an 80-column Printer. The Printer also prints Monitor displays and reports when the print function is selected. The CPU provides a 24K byte report buffer and 8K byte logging buffer for output to the Printer. As soon as the data is loaded into the buffer, the system is available for other operating functions. All log entries, reports and display printouts include the date and time.

REMOTE UNIT INTERROGATION

F1 ENTER AUTO REMOTE TEST CYCLE PARAMETERS
F2 TOGGLE AUTO REMOTE TEST CYCLE MODE
F3 MANUALLY TEST REMOTE UNIT
F4 MANUALLY ACTIVATE REMOTE SIGNAL FOR UNIT
F5 MANUALLY TEST ALL REMOTE UNITS NOW
F6 SELF-TEST THE RF MODEM
F7 RESET THE RF MODEM
F8 ABORT TEST CYCLE IN PROGRESS
F9 ALARM MENU
F10 EXIT

AUTO REMOTE CYCLE SETUP
NEXT AUTO REMOTE TEST CYCLE START TIME (HH:MM)
REMOTE TEST CYCLE INTERVAL TIME 24 HR
BT2 POLLING RANGE (1 -1)
ZID REPORTING RANGE (1 -1)

An optional plug-in card may be used to provide alarm and trouble input/outout. This card includes two inputs for detection devices and two outputs for audible devices. The inputs may be used for reporting alarms and troubles for receiving station monitoring equipment. If used, they report to 2999 and 3000 in the D-500 Plus. The outputs provide for remote audible signalling of alarms and troubles received at the D-500 Plus. The remote audible may be enabled or disabled at the Main Screen.

Operation of the D-500 Plus in the event of an ac power failure is provided with an Uninterruptible Power Supply.

Monaco Enterprises INC.
E. 14820 SPRAGUE AVE., P.O. BOX 14129, SPOKANE, WASHINGTON 99214 (509) 926-6277

D-500 PLUS RADIO ALARM SYSTEM

REPORTS

The D-500 Plus provides two management information report formats: user generated and Plus generated. The NON-EMERGENCY CARD provides user programmable space for reports, lists, calendars, inventories, etc. The Plus automatically stores system activity information which it can collate in different ways to provide reports as needed. These reports are identified in the Features list.

D-500 PLUS DISPATCH INFORMATION DISPLAYS

All screens include the day, date, time, operator name and installation name. A menu of functions available is displayed at the bottom of the screen. To perform a function, the operator simply finds the name of the desired function on the display and presses the keyboard function key listed next to it.

MAIN SCREEN

This screen is displayed during normal conditions. It shows a list of all apparatus and current status: not available, standby, dispatched, and available. The screen also shows Daily Notes-temporary conditions which affect alarm response generally. The Notes are printed with Alarm Cards. The Main Screen can be referred to from any Alarm Card display.

CALL DIRECTORY

The Call Directory provides up to 30 listings including organization, contact person, position, office and home phone numbers, and beeper or radio numbers. This information can be referred to from any Alarm Card.

ALARM CARDS

Dispatch cards for response to alarms may be entered by the user for zones, aircraft emergencies and non-zone emergencies. Zone reports may be received from the D-500 System, on other receiving equipment, by telephone, etc. The D-500 Plus is designed to provide a centralized, computerized source of dispatch information.

When an alarm signal is received from a D-500 Building Transceiver (BT2), a notification window is automatically overlayed on the screen currently displayed on the Monitor.

```
4/29/87            FIRE ALARM              16:20
ZID: 1             BLDG: 1234         PRIORITY: 1
FACILITY: HOSPITAL
ADDRESS: 4532 E. MARKET
XSTREET: Main

PRESS "t" TO ATTRIBUTE ALARM AS TEST
PRESS ANY OTHER KEY TO ACKNOWLEDGE ALARM
```

If the alarm is acknowledged, the Alarm Card for that zone is displayed automatically.

ALARM MENU

- F1 BUILDING NUMBER
- F2 FACILITY NAME
- F3 ADDRESS
- F4 BOX NUMBER
- F5 ZID NUMBER
- F6 AIRCRAFT MODEL
- F7 EMERGENCY MENU
- F10 EXIT

Alarm Cards for zones that are reported to the central station by any other method (other receiving equipment, telephone, etc.), for aircraft emergencies and for non-zone emergencies can be called up for display or placed in the pending buffer manually through the Alarm Menu. It only takes a couple of key strokes.

All Alarm Cards are assigned a display priority. If alarms are received during an active alarm, the Alarm Cards are placed in a pending buffer and lined up for display by the priority. Cards in the pending buffer can be viewed and printed without removing the active alarm.

ZONE ALARM CARDS

Three types of Zone Alarm Cards are provided to match specific reporting zones: Fire, Security, Auxiliary.

FIRE ALARM CARD: Complete information needed to identify the zone is provided–the zone identification number, building number, facility name, zone description, address, cross street, and box number. This Alarm Card includes three screens: RESPONSE. PRE-PLAN, TROUBLE.

*The RESPONSE screen lists the apparatus to dispatch and shows water supply information and hazards and precautions for response personnel to observe.

*The PRE-PLAN screen shows the plan of action for responding to a fire in this zone.

*The TROUBLE screen lists the detection equipment in the zone and provides space to enter a Trouble Log.

SECURITY ALARM CARD: The RESPONSE screen includes the same type of location information as the Fire Card. It also provides response instructions and zone occupancy information. The PRE-PLAN screen lists the type of alarm equipment installed, who to notify, hazards and precautions. Required reports may be listed by form number or title.

AUXILIARY ALARM CARD: This card provides for zones reporting on special monitoring or supervisory devices--water level indicators, temperature sensors, pump activity, etc. Its one screen provides location information, equipment description and response/notification instructions.

AIRCRAFT EMERGENCY CARD

This Card can be stored in the D-500 Plus for manual display in the event of an aircraft emergency. Individual Cards can be entered for different models and, if needed, for specific emergencies. The RESPONSE screen provides space to fill in a description of the event: Location, Souls on Board, Fuel Load, Munitions/Hazardous Cargo. This screen also lists response apparatus and shows hazards and precautions. The PRE-PLAN screen identifies the local configuration and the plan of action for responding to this emergency.

EMERGENCY CARD

This dispatch card is used for manual display of response instructions for areas that are not included in an automatic detection system. Emergency Cards might be entered for parks, stadiums, runways, or buildings under construction. The Card shows the name and address of the property, the emergency situation, and response instructions.

APPARATUS STATUS/DISPATCH SCREEN

The apparatus list from the Main Screen can be overlayed on any of the Alarm Cards. The status of the apparatus listed on the Card for response can be checked. Then the apparatus can be dispatched with one key stroke.

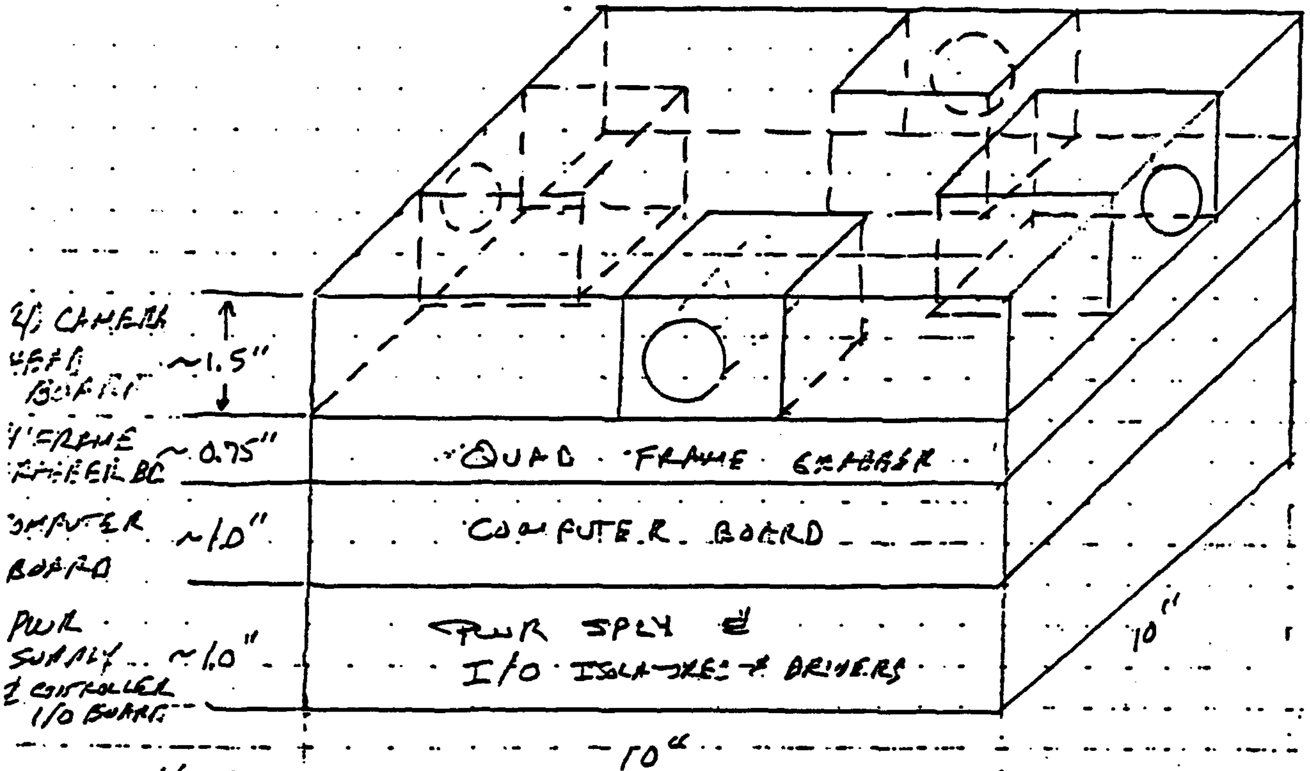
ORDERING INFORMATION

Part Number	Description
225-130-00	D-500 Plus Radio Alarm System: Includes CPU/Keyboard, Monitor, Printer, RFM-5000, Software, Backup Floppy Disks, Antenna, Lightning Protection, Coaxial Cable Assemblies
225-131-00	D-500 Plus Radio Alarm System with 20 Minute Uninterruptible Power Supply (UPS)
225-132-00	D-500 Plus Radio Alarm System with 4 Hour UPS
225-133-00	D-500 Plus Radio Alarm System with 24 Hour UPS
225-134-00	D-500 Plus Radio Alarm System with 60 Hour UPS
225-170-00	Graphics Display System: Includes High Resolution Monitor (1024 x 1280), D-500 to Graphics System Interface Board, Graphics Adapter Board and Integrated Graphics Software
176-146-00	Remote Audible PCB Assembly (Optional to provide zone input, output for protection at the receiving equipment location and remote alarm and trouble audible devices
176-149-00	Remote Communication Driver Assembly (Optional to provide four communications ports between the D-500 Plus and Remote Monitors)

2/4/92

FIRE SENTRY MUFES MODULES

(4) CAMERAS w/ 90° FIELD OF VIEW
IN (4) QUADRANTS



TOTAL HEIGHT 4.25"

ESTIMATED WEIGHT

(4) CAMERAS	16 oz
FRAMEGRABR	20 oz
COMPUTER	30 oz
PWR SPLY	20 oz
TOTAL	86 oz
TOTAL	5 lb. 4 oz

POWER REQMTS

(4) CAMERAS	4 WATTS
FRM GRBR	7 WATTS
COMPUTER	12 WATTS
PWR SPLY	2 WATTS
	25 WATTS

{ +5V @ 4A, −5V @ 1A } = 25 WATTS

OR +12V @ 2.1A = 25 WATTS

OR +28V @ 0.9 A = 25 WATTS

APPENDIX D

PERFORMANCE DESCRIPTION

PERFORMANCE DESCRIPTION

Aircraft Fire Sentry -- Remote Fire Detection and Alarm Reporting System

1. Abstract:

This Performance Description (PD) describes the standards for a commercially produced, portable remote fire detection and alarm reporting system (Aircraft Fire Sentry, AFS). The AFS is intended to automatically scan, using multiple sensors, and detect fires aboard unattended large cargo aircraft. Once a fire has been detected, the AFS then notifies the fire department by a radio frequency (RF) link. At the aircraft, a strobe and siren provide visual and audible indications of alarm. The unit shall be assembled from current commercially available fire detection hardware.

2. Features:

   A. Performance:

      1. The unit, while operating, shall continuously scan for smoke and flame by the use of at least two remotely located smoke detectors and one ultraviolet flame detector.

      2. The AFS shall have the capability of detecting and reporting fires caused by NFPA Class A, B & C (trash/wood/paper, fuel or electrical) sources.

      3. The smoke detectors shall be capable of transmitting their RF alarm messages to the AFS a minimum distance of 60 feet.

      4. The radio transmitters in the AFS unit shall be powerful enough to transmit the alarm message a minimum of 5800 ft and be of a minimum received signal strength of -107 dBm.

      5. Operational ranges of all equipment shall be at least -20°F to 120°F.

      6. The AFS shall be capable of operating and recharging its batteries by the use of AC current.

      7. The AFS shall have an internal stand-by DC power source capable of providing a minimum of 60 hours duration.

      8. All hardware comprising each AFS shall be new and free from defects.

B. Function Switches and Lights (Controls):

1. AFS Unit Enclosure

   a. On the exterior front of the AFS, there shall be one main power switch and one system reset switch. The main power switch shall activate all components internal to the AFS unit enclosure. Likewise, the reset switch shall be capable of resetting all systems inside the AFS unit enclosure when necessary.

   b. The main power switch shall be a positive detent rocker switch.

   c. The reset switch shall be a spring-loaded positive detent rocker switch.

   d. The colors of the respective switches shall not be identical.

   e. Provide four separately colored LED lights on the front panel that indicate:

      Power On
      Low Battery
      Trouble
      Transmitting

   f. Provide LED lights inside the AFS enclosure that indicate which zones have been activated (for testing, troubleshooting and verification purposes).

   g. Provide a manual pull alarm station control handle located on the front panel.

2. Remote Smoke Detectors:

   a. Each remote smoke detector shall have a red LED indicating the batteries are installed and have sufficient charge.

   b. Each remote smoke detector shall have a manual test button to simulate an alarm condition.

C. Packaging:

1. The AFS unit enclosure shall be a durable impact-resistant environmentally sealed enclosure. Maximum exterior dimensions shall not exceed 14"x14"x20". Total weight shall not exceed 40 pounds.

2. A storage compartment shall be provided inside the enclosure for system peripherals -- the volume to be no less than 342 cubic inches, and no less than 4 inches in height.

3. Means shall be provided to access all interior components quickly and easily. Components mounted in modular fashion on an extendible equipment rack meets this requirement.

4. Provide 3 carrying handles -- one on top and one on each side.

D. Power:

1. Provide the most efficiently sized AC rechargeable 12 VDC battery with the capacity to power all equipment for a minimum of 60 hours.

E. Electronics:

1. Provide all necessary circuits to detect, transmit, relay and activate all detectors, transmitters and audio/visual indications of an alarm.

2. Provide a minimum of 5 separate zones of surveillance for the AFS transceiver assembly and addressed as follows: one zone monitors system faults, one monitors the flame detector, one for each of the two smoke detectors and one for the manual pull station.

3. Operating radio frequency for the relay transmitters shall be 138.925 Mhz unless otherwise specified for a specific installation.

F. Antennas:

1. The AFS shall have as its main transmitting antenna a 40" collapsible model, with a magnetic base for positioning on top of the enclosure.

2. The AFS shall have a small, suitable sensor antenna capable of picking up alarm signals generated by the wireless remote smoke detectors at a distance of 60 feet.

G. Detectors:

1. Smoke Detector

a. The smoke detectors shall be 9 VDC battery powered, wireless remote, photoelectronic units.

b. Factory rated smoke obscuration sensitivity shall be no greater than 3.1% per foot $\pm$0.5%.

c. Operating frequency shall be 303.875 Mhz unless otherwise specified.

d. Each smoke detector shall be fitted with an internal audible horn capable of at least 85 dB at 10 feet.

e. Each smoke detector shall not deviate greatly from the approximate physical characteristics of 6 inches diameter and 12 ounces weight.

f. Provide a hook or similar means of hanging each detector in the aircraft.

2. Ultraviolet Detector

a. The ultraviolet flame detector shall operate on 12 VDC system power.

b. The ultraviolet detector shall be placed in the AFS enclosure such that it provides for the greatest cone of vision out the front of the AFS unit.

c. Normal response time for the UV detector shall be no longer than 3 seconds at 12 feet for a 12-inch diameter hydrocarbon fire.

d. The AFS can be fitted with any new and proven flame detection technology in lieu of ultraviolet detectors provided that there is no sacrifice in any other of the PD requirements as set forth in this document.

e. Any new technology replacement for UV flame detection shall meet or exceed the response time and performance of the UV detector. Particular attention should be paid to the power consumption of the replacement flame detection system.

H. Manual Alarm Initiation

1. Provide a means of manually activating an alarm condition at the AFS unit (Refer to 2.B.1.g.).

2. The device shall be activated simply but deliberately, and be resettable.

I. Alarm Indications

1. Audible

   a. Provide a remotely located 12 VDC weatherproof siren (outside the aircraft) capable of 114 dB at 10 feet.

   b. Provide a cable of at least 25 feet to connect the siren to the AFS unit.

   c. Provide a horn at each smoke detector (Refer to 2.G.1.d.).

2. Visual

   a. Provide a strobe, integral with the siren, of weather-tight construction.

   b. The strobe shall produce a minimum of 70,000 candlepower and be fitted with a red lens.

   c. The AFS shall produce visual alarm messages on the screen of the receiving terminal at the base fire department. These messages shall be capable of displaying information on: 1) the nature of the alarm (smoke, UV, manually activated), and 2) the location of the alarm (position on ramp or tail number of aircraft). Visual messages on screen of receiving terminals are generally accompanied by an audible beep or tone to alert the person monitoring such stations. It is a requirement that all visual messages be accompanied by audible means.

3. <u>Deployment</u>:

The Aircraft Fire Sentry shall be designed and constructed such that it can be maintained, transported and deployed by a single person. The AFS shall be simple enough in use (set-up) that a single person can deploy the AFS in an aircraft in less than 5 minutes. Likewise, to remove the system from the aircraft, it must be as simple, and take no longer than 5 minutes. The connectors for AFS system antennas and cables shall all be sufficiently different as to make it impossible to misconnect any of the system peripherals during deployment.

A brief summary of the typical installation procedure is as follows:

1. Verify all batteries fully charged.
2. Bring AFS aboard aircraft.
3. Position AFS to maximize flame detector cone of vision.

4. Position one smoke detector at each end of the cargo bay at ceiling height (no farther than 60 feet from AFS unit).
5. Connect system antennas (2).
6. Connect strobe/siren to AFS unit via its cable and hang the strobe/siren assembly outside of the fuselage.
7. Turn power switch on.
8. Manually activate an alarm condition to test transmission and verify test at fire department (optional).

4. <u>Marking and Labeling</u>:

The Aircraft Fire Sentry enclosure shall have easily identifiable marking and labeling on its exterior. The information shall include, but not be limited to:

- Name and purpose of assembly (i.e., Aircraft Fire Sentry, portable fire detection and notification system)
- Unit and serial number
- Deployment instructions
- Power requirements
- Name and purpose of each functional exterior component or LED (i.e., power = on/off, sensor antenna, system antenna, etc.)
- Precautions